# Michigan DOT User Guide for Mechanistic-Empirical Pavement Design

*Interim Edition*

**March 2021**

Michigan Department of Transportation

**CONSTRUCTION FIELD SERVICES DIVISION**

# Engineering Preamble

This manual provides guidance to administrative, engineering, and technical staff. Engineering practice requires that professionals use a combination of technical skills and judgment in decision making. Engineering judgment is necessary to allow decisions to account for unique site-specific conditions and considerations to provide high quality products, within budget, and to protect the public health, safety, and welfare. This manual provides the general operational guidelines; however, it is understood that adaptation, adjustments, and deviations are sometimes necessary. Innovation is a key foundational element to advance the state of engineering practice and develop more effective and efficient engineering solutions and materials. As such, it is essential that our engineering manuals provide a vehicle to promote, pilot, or implement technologies or practices that provide efficiencies and quality products, while maintaining the safety, health, and welfare of the public. It is expected when making significant or impactful deviations from the technical information from these guidance materials, that reasonable consultations with experts, technical committees, and/or policy setting bodies occur prior to actions within the timeframes allowed. It is also expected that these consultations will eliminate any potential conflicts of interest, perceived or otherwise. MDOT Leadership is committed to a culture of innovation to optimize engineering solutions.

The National Society of Professional Engineers Code of Ethics for Engineering is founded on six fundamental canons. Those canons are provided below.

Engineers, in the fulfillment of their professional duties, shall:

1. Hold paramount the safety, health, and welfare of the public.
2. Perform Services only in areas of their competence.
3. Issue public statement only in an objective and truthful manner.
4. Act for each employer or client as faithful agents or trustees.
5. Avoid deceptive acts.
6. Conduct themselves honorably, reasonably, ethically and lawfully so as to enhance the honor, reputation, and usefulness of the profession.

## FOREWORD

This manual has been prepared to outline how the Michigan Department of Transportation (MDOT) designs the pavement cross-section according to the Mechanistic-Empirical Pavement Design Guide (MEPDG) from the American Association of State Highway and Transportation Officials (AASHTO). This manual provides guidance on utilizing AASHTO's software package *Pavement ME Design, version 2.3* to arrive at a pavement cross-section that can be utilized on MDOT pavement projects.

Inquiries concerning the information presented in this manual may be directed to the individuals listed in Section 1.6 – Contacts.

The manual can be downloaded from MDOT's website:

www.michigan.gov/mdot

Select these headings from the navigation bar (left side of the page), in the following order:

Reports, Publications and Specs

⇩

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Manuals and Guides

Under the Construction Field Services – Manuals area, select the link "Mechanistic Empirical Pavement Design user Guide"

# Michigan Department of Transportation (MDOT) Mechanistic Empirical Pavement Design Guide Interim Edition

## Table of Contents

# Chapter 1 – Introduction

## 1.1 – Introduction

The American Association of State Highway Transportation Officials (AASHTO) has adopted a mechanistic-empirical (ME) method as the recommended method for designing a pavement cross-section. This ME method can be found in AASHTO's publication *Mechanistic-Empirical Pavement Design Guide, A Manual of Practice* and the accompanying software Pavement ME Design. The Michigan Department of Transportation (MDOT) currently uses the ME design method as its standard for cross-sectional pavement design for new and reconstruct pavement projects. This replaces the previously accepted design method, *AASHTO's Guide For Design of Pavement Structures, 1993*, commonly referred to as AASHTO 1993. Information related to the AASHTO 1993 method can be found in APPENDIX A – DARWin Inputs (AASHTO 1993 Method) of this User Guide.

This User Guide is intended to help pavement designers use the Pavement ME Design software to design the pavement cross-section on MDOT projects. It provides details on software operation, design types to be used with ME, the inputs to be used, and how to assess the design results. This user guide is based on version 2.3 of the Pavement ME Design software.

Note that pavement designs may be subjected to the Life Cycle Cost Analysis (LCCA) method, as outlined by the MDOT *Pavement Selection Manual*. These designs will be conducted by the MDOT Pavement Management Section of the Construction Field Services Division. See this manual for further details on when LCCA is required by MDOT.

## 1.2 – Background

AASHTO 1993 is largely based on the AASHO Road Test of 1958-59 (the T wasn't added to AASHTO until 1973). In the Road Test, many different cross-sections were built on closed loops. Trucks were driven on the loops and the performance of the different cross-sections was observed periodically. This is known as an empirical method. Conversely, the mechanistic-empirical method utilizes the theories of mechanics to estimate the pavement response in the form of stresses and strains, to the applied loads of truck traffic (the mechanistic portion of ME). Damage is estimated from these stresses and strains, and accumulated over the pavement's design life. The damage is then converted to typical pavement distresses by way of transfer functions. These transfer functions are based on, and calibrated with, pavement distress information observed on in-service pavements (the empirical portion of ME).

There are many reasons why an improved design procedure was needed to meet the limitations of previous design methods *(1)*:

- Truck traffic volumes have increased significantly since the 1960's. It is not uncommon to be designing for over 50 million equivalent single axle loads (ESAL's). Yet, the data from the AASHO Road Test encompassed no more than 1.8 million ESAL's. It is believed that the extrapolation needed to design for modern traffic levels has resulted in overly conservative thicknesses.

- Need for improved rehabilitation design procedures. Rehabilitation was not part of the AASHO Road Test. Empirical design procedures for rehab were added in later editions of AASHTO's design guide.
- The AASHO Road Test occurred in one location (Ottawa, Illinois) so the effect of different climates is not directly included.
- The AASHO Road Test involved only one subgrade type. There are many different subgrades around the country.
- Only one asphalt mix and one concrete mix were used at the AASHO Road Test so the effect of different mix and material types is not included.
- Two unbound dense granular material types were used at the AASHO Road Test, so the effect of other granular material types (open-graded, stabilized, etc.) are not included.
- Truck axle configurations, suspensions, and tire pressures have changed significantly from those used on the AASHO Road Test.
- Construction methods, materials, and designs have changed significantly since the AASHO Road Test.
- Drainage features were not included as part of the AASHO Road Test so its effects are not included.
- Since the Road Test was only two years long, the long-term effects of climate and aging of materials are not included.
- Serviceability is the method from the AASHO Road Test for measuring pavement performance. It is directly related to thickness in the design equations that came out of the Road Test. However, many distress types are not related to thickness (thermal cracking, faulting, etc.).
- Reliability with the empirical design method was used as a multiplier of the traffic loadings, which resulted in excessive thickness at higher truck traffic levels.

Because the ME design method includes climatic effects, more material properties, design features (joint spacing, etc.) and the consideration of non-structural failure mechanisms, a reduction of early pavement failures and an increase in pavement life is anticipated *(1)*. In addition, several other benefits of mechanistic-empirical design were listed in the 1986 edition of *AASHTO's Guide For Design of Pavement Structures (2)*:

- Estimating the effect of new loading conditions (high tire pressures, different axle configurations, etc.).
- Increased understanding of the effect, and utilization of, locally available materials.
- Forensic capability for investigating under or over-performance of pavement sections.
- Inclusion of the effects of material aging.
- Inclusion of the effects of seasonal variation (climate).
- Evaluating the effects of erosion.
- Quantifying the effect of improved drainage.

An additional benefit of ME design is its modularity and ability to be adapted to new understandings of pavement response and failure mechanisms. As new and improved models are developed and have gained acceptance, they can be added, or "plugged in" to the method and software.

The major differences between ME and AASHTO 1993 can be found in Table 1-1.

**Table 1-1. Differences Between ME and AASHTO 1993**

| | AASHTO 1993 | Mechanistic-Empirical |
|---|---|---|
| **Basis** | Empirical observation from the 1958-59 AASHO Road Test | Theories of mechanics |
| **Original Calibration** | AASHO Road Test – Ottawa, Illinois | LTPP test sections from around the US/Canada |
| **Traffic Characterization** | Equivalent single axle load | Axle load spectra |
| **Materials Inputs** | Very few | Many |
| **Climatic Effects** | Very limited – can change a few inputs based on season | Integral – weather data from 1000+ US/Canadian weather stations included |
| **Performance Parameter** | Present Serviceability Index | Various pavement distresses, IRI |
| **Output** | Thickness | Performance prediction (distresses and reliability) |

In 1998, a National Cooperative Highway Research Program (NCHRP) research project was initiated to pull together existing mechanistic pavement models under one design methodology and software package. This project, known as NCHRP 1-37a, produced the mechanistic-empirical pavement design guide, or MEPDG. The software that was produced to go along with the design method also became known as MEPDG. It was considered a research-grade software until AASHTO took over ownership and began selling it commercially in 2011 after the user interface was redesigned. Initially, it was called DARWin-ME, but in 2013 it was renamed Pavement ME Design.

## 1.3 – Michigan ME Research

MDOT has been evaluating the ME design method and sponsoring ME-related research since the first version of the software was released in 2004.

The first research project initiated to deal directly with the new ME design procedure ran a sensitivity analysis and validation of the models. This project involved checking the sensitivity of the distress predictions for new and reconstruct asphalt and concrete designs to variances in the inputs. The inputs that were considered sensitive can be found in bold in the various input tables in this user guide. The validity of the predictive models for Michigan use was also checked by comparing ME predictions to observed performance for 5 asphalt and 5 concrete projects. ME was found to produce reasonable results, but due to various over or under-predictions, local calibration was recommended. The final report

*Evaluation of the 1-37A Design Process for New and Rehabilitated JPCP and HMA Pavements* (Report RC-1516) was published in October of 2008.

At about the same time a project to test the coefficient of thermal expansion (CTE) of typical concrete mixes used for paving in Michigan, was sponsored. It had been reported that the ME design procedure for rigid pavements was sensitive to CTE. In addition, MDOT did not have any test data for CTE. Most of the literature on CTE stated that the coarse aggregate type had the biggest impact on CTE. So, a single mix design was used with eight different coarse aggregate sources, representing five different aggregate types. The concrete was batched and delivered by the same concrete batch plant. The five aggregate types were: limestone, dolomite, gravel, slag, and trap rock. All but the trap rock are typically used in Michigan with limestone and dolomite being used the most. The final report *Quantifying Coefficient of Thermal Expansion Values of Typical Hydraulic Cement Concrete Paving Mixtures* (Report RC-1503) was published in January 2008.

Because ME changes the traffic inputs significantly from ESAL's to axle load spectra and various other truck configuration inputs, a traffic-specific research project was initiated. The sensitivity of the various traffic inputs was investigated. Data from weigh-in-motion (WIM) and classification permanent traffic recorders (PTR) was utilized to develop statewide average inputs as well as to cluster the PTR's into groups with similar characteristics. To determine significance, typical designs were used to investigate the impact of time to failure using statewide and cluster inputs. The final report *Characterization of Truck Traffic in Michigan for the New Mechanistic Empirical Pavement Design Guide* (Report RC-1537) was published in December 2009. To account for updated traffic, cluster methods, and split statewide averages into freeway and non-freeway, this report was superseded by the report *Updated Analysis of Michigan Traffic Inputs for Pavement-ME Design* (Report SPR-1678), published in August 2018.

Since local calibration was recommended by the initial sensitivity study (RC-1516), a calibration project was sponsored. Two other separately approved research projects were rolled in to make this a three part project:

- Part 1: materials testing of typical Michigan asphalt mixes.
- Part 2: sensitivity of rehabilitation designs
- Part 3: local calibration to Michigan conditions

In part 1, 64 loose mix samples representing over 40 different asphalt mixes were sampled from various projects around the state. Dynamic modulus ($|E^*|$) and indirect tensile strength (IDT) were tested on these loose samples. In addition, binder samples of the typical superpave performance grades (PG) used in Michigan were collected and binder shear modulus ($|G^*|$) was tested. Mix creep compliance was estimated from the dynamic modulus master curve. The modified Witczak model for estimating the dynamic modulus using mix properties was locally calibrated using the test results. In addition, an artificial neural network (ANN) was developed to estimate the dynamic modulus, IDT, and creep compliance from various volumetric properties. A software package, DynaMOD was developed to house the test results and provide a method for putting the test results in the proper format for importing into the ME software.

The locally calibrated modified Witzcak and ANN models for predicting dynamic modulus, IDT, and creep compliance were also included in the DynaMOD software. The final report *Preparation for Implementation of the Mechanistic-Empirical Pavement Design Guide in Michigan, Part 1: HMA Mixture Characterization* (Report RC-1593) was published in March 2013.

Part 2 involved a sensitivity analysis and evaluation of ME predictions for rehabilitation designs. Despite its title, the initial sensitivity study, RC 1516, never made this evaluation for rehabilitation designs. Similar to RC-1516, a sensitivity analysis was conducted on the inputs specific, or unique, to rehabilitation designs. Also, the distress predictions from ME were compared to observed distresses for 40+ in-service rehabilitation projects. The inputs deemed as sensitive are in bold in the input tables in this user guide. The final report *Preparation for Implementation of the Mechanistic-Empirical Pavement Design Guide in Michigan, Part 2: Evaluation of Rehabilitation Fixes* (Report RC-1594) was published in August 2014.

Local calibration of version 2.0 of the ME models was conducted in Part 3. Many in-service pavements were utilized for this calibration: 20 jointed plain concrete pavement (JPCP) reconstruct projects, 108 asphalt reconstruct projects, and 41 rehabilitation projects from part 2. The resulting recommended calibration coefficients can be found in Chapter 6. The final report *Preparation for Implementation of the Mechanistic-Empirical Pavement Design Guide in Michigan, Part 3: Local Calibration and Validation of the Pavement-ME Performance Models* (Report RC-1595) was published in December 2014. To account for the update to version 2.3 and recalibrate the software, this report was superseded by the report *Recalibration of Mechanistic-Empirical Rigid Pavement Performance Models and Evaluation of Flexible Pavement Thermal Cracking Model* (Report SPR-1668), published in November 2017. Note that the recommended concrete calibration coefficients are not used by MDOT because the ME thicknesses predicted using global coefficients have less bias than those using the calibration coefficients as compared to AASHTO 1993 thicknesses. This is likely due to the limited amount of pavement sections and distress data points to calibrate to. Additional sections and more data points should improve the calibration results, so future recalibration will be considered.

Two other projects involving modulus values of subgrade and unbound granular layers were not specifically initiated because of ME, but their results do provide ME-related information. The reports are *Pavement Subgrade MR Design Values for Michigan's Seasonal Changes* (Report RC-1531) published July 2009 and *Backcalculation of Unbound Granular Layer Moduli* (Report RC-1548) published August 2011.

### 1.4 – Design Types

The following pavement design types will be designed with ME, and are therefore covered by this User Guide:

- New/reconstruct asphalt
- New/reconstruct JPCP
- JPCP overlays ≥ 6”
- Rubblized concrete with asphalt resurfacing

## 1.5 – User Guide Layout

This user guide is separated into the following chapters:

1. Introduction
2. Software Operation: provides a basic understanding of the different areas and the functions of the Pavement ME Design software
3. Design Process: a high-level set of steps to gather information, create an ME design, and arrive at a finished design
4. General Inputs: values to be used for design type, pavement type, design life, etc.
5. Performance Criteria and Reliability: distress thresholds and reliabilities to use for the various design types
6. Calibration Coefficients: calibration coefficients that are to be used for the various design types
7. Traffic Inputs: values to be used for the traffic inputs, description of the traffic inputs request process, and a description of cluster selection
8. Climate Inputs – method for choosing the weather station
9. Asphalt Pavement (New) Layer Inputs: values to be used for new asphalt layers
10. Concrete Pavement (New) Layer Inputs: values to be used for new concrete layers
11. Base/Subbase Layer Inputs: values to be used for base and subbase layers
12. Subgrade Layer Inputs: values to be used for the subgrade layer
13. Existing Layer Inputs for Rehab Design: values to be used for any existing layers as part of a rehabilitation design
14. Assessing the Results/Modifying the Design: description of the output, method for determining if the design should be accepted, and how to modify the design when it is not acceptable
15. Appendices: large input tables (axle load spectra, etc.), example designs, and DARWin 3.1 (AASHTO 1993) inputs

Each chapter that involves inputs will list the values to be used in table format at the beginning of the chapter. This is followed by more detailed description of each input.

## 1.6 – Contacts

This user guide and oversight of the ME design method use in Michigan, is overseen by the Pavement Management Section at Construction Field Services Division. The following representatives can be contacted for further information:

Michael Eacker, Pavement Design Engineer *(ME Software Administrator)*
eackerm@michigan.gov / (517) 322-3474
Justin Schenkel, Pavement Design Engineer
schenkelj@michigan.gov / (517) 636-6006
Jami Trudelle, Pavement Design Engineer
TrudelleJ1@michigan.gov / (517) 636-4920

## Chapter 2 – Software Operation

### 2.1 – Access

MDOT has a multi-user license of Pavement ME Design with a maximum limit of 9. Many users can have the software on their computers, but we can have up to 9 users at any one time with Pavement ME Design open. The software resides on each user's computer, however, upon starting the program, it checks with a license service application residing on a central server to make sure a license is available. If a license is available, the software opens, and the user can proceed with using it. Figure 2-1 shows an example in which 6 users are currently using Pavement ME Design and the cross-hatched user wants to use it. Since we have a maximum of 9, the cross-hatched user would be given access.

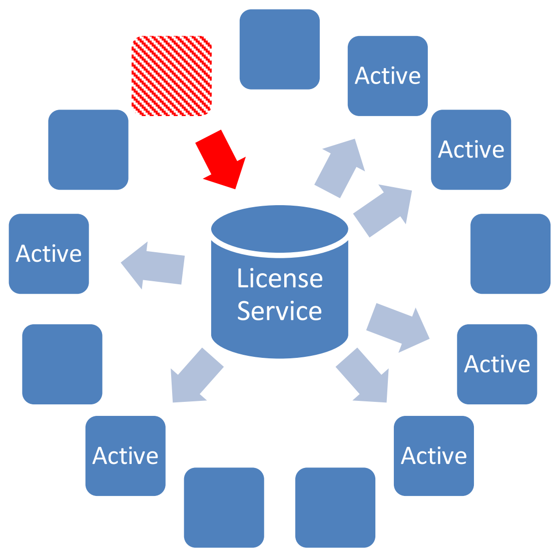



**Figure 2-1. Example of How a Multi-User License Works**

### 2.2 – Help Resources

The software comes with a help manual that goes into more detail on software operation than this user guide does. The *Help Manual* can be opened by clicking the 'Help' button on the Menu Bar. An HTML or PDF version of the *Help Manual* is available. The user can select the version they want to use by changing the 'Help Type' input in the Options tab (see Section 2.6.2.7 – Other Nodes).

Each design type has a section in the *Help Manual* that describes all the screens/inputs necessary for that design type. Both the HTML and the PDF version provide quick links to the different sections using the Bookmarks pane along the left side. If the Bookmarks pane is not open in the PDF, click the ribbon icon along the left side of the help file screen as shown in Figure 2-2:

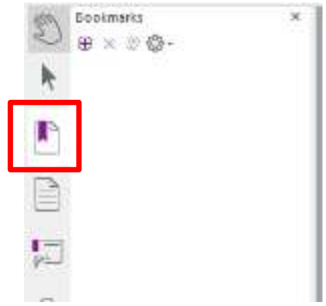



**Figure 2-2. Opening the Bookmarks Pane in the PDF**

In addition, the Pavement Management Section in the Construction Field Services Division can assist with software operation, access codes, and design inputs. See Section 1.6 – Contacts for contact information.

## 2.3 – Starting the Software

To start the software, double click the Pavement ME Design shortcut on the desktop or select it from the Programs area in the Windows Start menu, as shown in Figure 2-3.

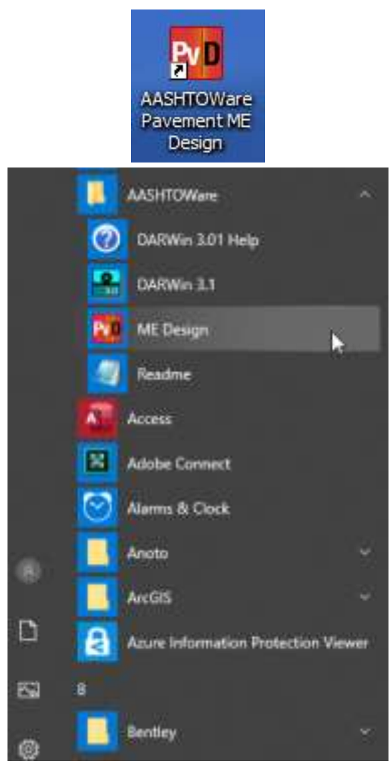



**Figure 2-3. Two Ways to Start Pavement ME Design (Windows 10 Shown)**

The Pavement ME Design splash screen will appear:

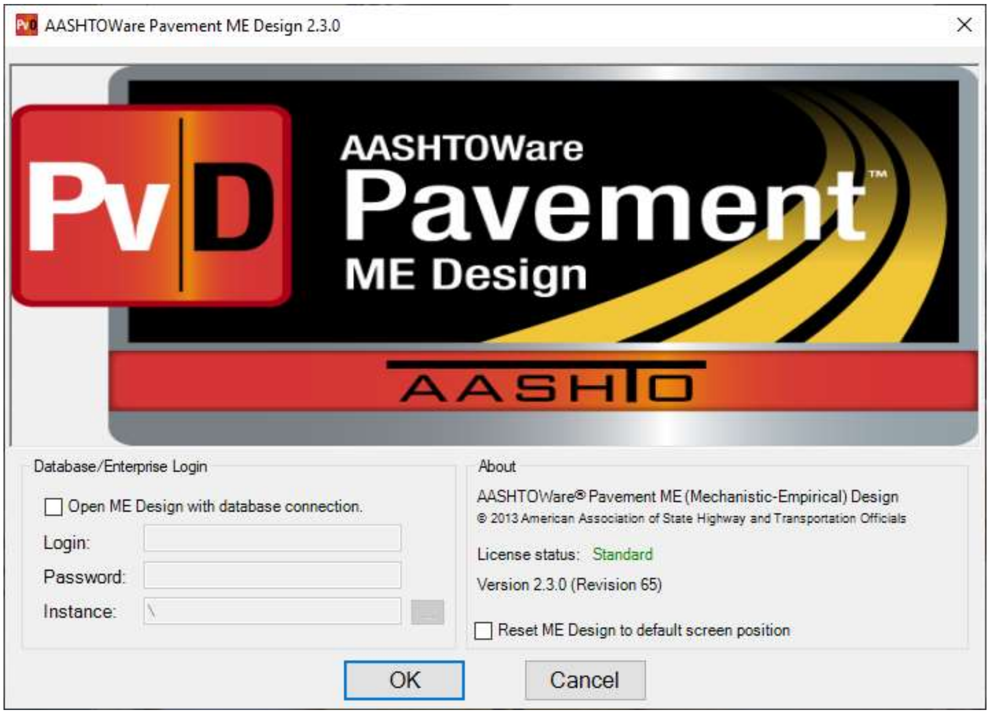


**Figure 2-4. Pavement ME Design Splash Screen**

The 'License status' and software version are shown in the 'About Pavement ME Design' pane (right side). If the 'License status' indicates 'Unlicensed' and/or the 'Version' is not '2.3.0', contact the Pavement Management Section (see Section 1.6 – Contacts) for assistance.

Leaving the 'Open ME Design with database connection' box unchecked will open the software without access to the ME database. If access to the ME database is desired, check the box and enter your Login and Password information. **Designs can be run the same with or without access to the database**. The difference is that with a connection to the database, users can search and open designs that have been saved to the database, and access pre-entered pavement layers, traffic data, and climate data. Currently, MDOT does not use the software database option. Press the 'OK' button to open the design interface.

Checking the box next to 'Reset ME Design to default screen position' will reposition all windows/panes in the design interface back to their default positions.

## 2.4 – Database Access

In order to access the database, a Login ID and Password will need to be assigned by the ME software administrator. In addition, the ME software administrator will provide database configuration settings that need to be entered. To enter these settings, click the button to the right of the 'Instance' box as shown in Figure 2-5.

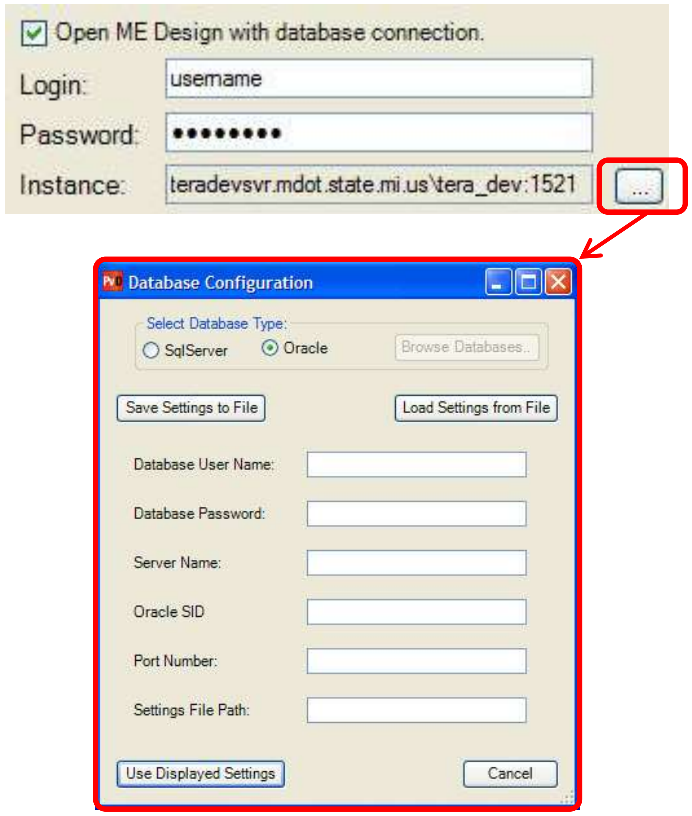



**Figure 2-5. Method for Entering Database Configuration Settings**

Make sure "Oracle" is chosen for 'Database Type' and enter the settings provided by the ME software administrator (see Section 1.6 – Contacts).

The buttons work as follows:

- Save Settings to File: Saves the entered settings to a file named 'init.xml'. It is highly recommended that the settings be saved. The user should choose to save them in a location the user will remember should they need to be retrieved.
- Load Settings from File: Allows the user to retrieve the settings from the 'init.xml' file if they are lost and need to be re-entered.
- Use Displayed Settings: Accepts the entered settings and returns to the Pavement ME Design splash screen.
- Cancel: Returns to the Pavement ME Design splash screen.

Once the settings have been entered and the user clicks 'Use Displayed Settings', they will not have to enter the configuration screen again unless the settings change. The ME software administrator will inform users if this occurs.

Details on additional features in the software when connected to the database can be found below in the remainder of this chapter.

## 2.5 – Multiple Options for Actions

For many actions within Pavement ME Design, there are multiple ways to perform the action. For example, there are three ways to open a new project:

1. Select the 'New' button from the Menu Bar
2. Right click 'Projects' in the Explorer Pane and select "New"
3. Press Ctrl and N at the same time

Another example is there are three ways to select a layer to show its properties in the Project Tab Pane:

1. Double click the layer under the 'Pavement Structure' folder in the Explorer Pane
2. Select the layer from the drop-down menu just above the Property Grid area
3. Single click the layer in the picture of the cross-section

The intent of this section is not to provide the full list of actions that have multiple options, but rather to make the user aware of the flexibility within the software. See the *Pavement ME Design Help Manual* for a list of shortcut keys.

## 2.6 – Pavement ME Design Window

Once the software opens, the user is presented with the Pavement ME Design window. This window is made up of distinct zones, or "panes", as noted in the figure below. See Section 2.7 – Screen Customization for information on how to customize the look of the Pavement ME Design window.

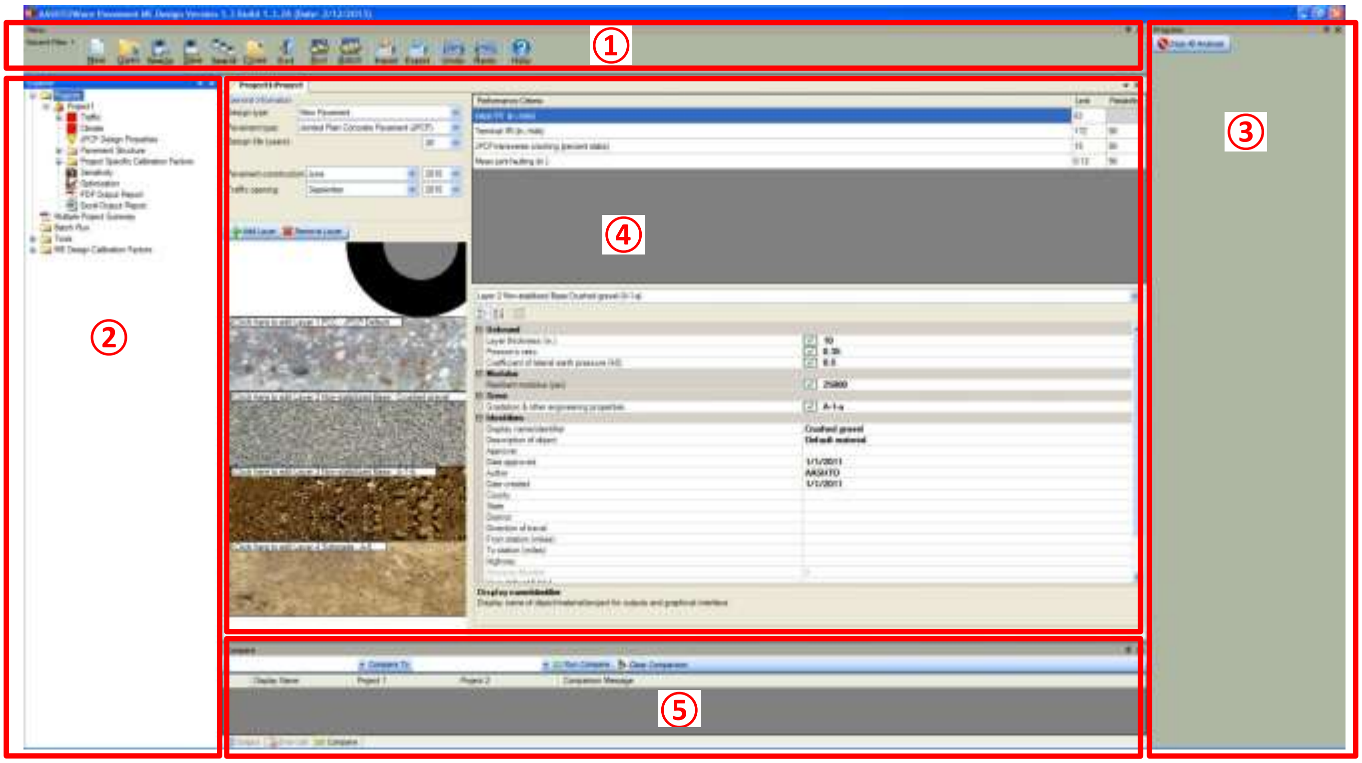



**Figure 2-6. Pavement ME Design Window Zones**

Pavement ME Design window areas:

1. Menu Bar
2. Explorer Pane
3. Progress Pane
4. Project Tab Pane
5. Output/Error/ Comparison Pane

General descriptions of these panes follow.

### 2.6.1 – Menu Bar

The Menu Bar contains buttons that will perform many of the most commonly used actions, such as creating new designs, saving files, running an analysis, etc.

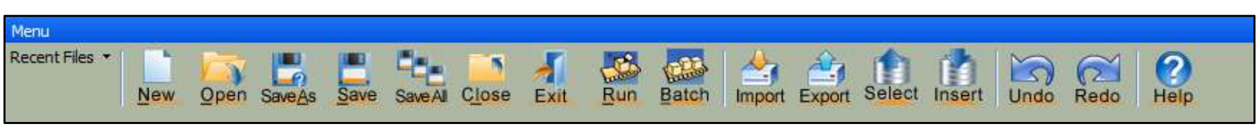



**Figure 2-7. Menu Bar**

- Recent Files: This is a drop-down menu where the last four opened projects can be re-opened. See Figure 2-8 below.

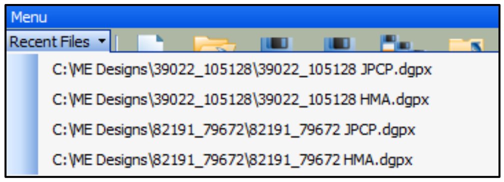



**Figure 2-8. Drop-Down of Most Recently Open Files**

- New: Starts a new project.
- Open: Opens an existing saved project.
- Save As: Saves the currently selected project (the one with the highlighted tab) with a new filename specified by the user. Do not use special characters in the filename, (i.e. semicolon).
- Save: Saves the currently selected project (the one with the highlighted tab). If the project has not been saved yet, the user will be prompted for a filename. Do not use special characters in the filename, (i.e. semicolon).
- Save All: Saves all the open projects. If they have not been previously saved, the user will be prompted for a filename. Do not use special characters in the filename, (i.e. semicolon).
- Close: Closes the currently selected project (the one with the highlighted tab). If it has not been saved, or there are changes since the last save, the user will be prompted to save it.
- Exit: Exits the program. The user will be prompted to save any unsaved projects.
- Run: Begins an analysis of the currently selected project (the one with the highlighted tab).
- Batch: Begins an analysis of multiple projects. The projects must be loaded into the Batch folder in the Explorer Pane before the analysis can begin.
- Import: Imports traffic, climate, or backcalculation files if one of those tabs is active.
- Export: Exports traffic, climate, or backcalculation inputs to an XML file if one of those tabs is active.
- Select: Saves files to the Pavement ME Design database. This button is only available when connected to the database.
- Insert: Extracts files from the Pavement ME Design database. This button is only available when connected to the database.
- Undo: Undoes the last change made on the currently highlighted tab.
- Redo: Reinstates the last change made using the undo button, on the currently highlighted tab.
- Help: Opens the *Help Manual*.

### 2.6.2 – Explorer Pane

The Explorer Pane is where the currently opened projects, options, calibration factors, and database functions (when connected to the database) are located. Multiple projects can be opened at one time, however, too many can make the Explorer Pane look cluttered as shown in Figure 2-9 below.

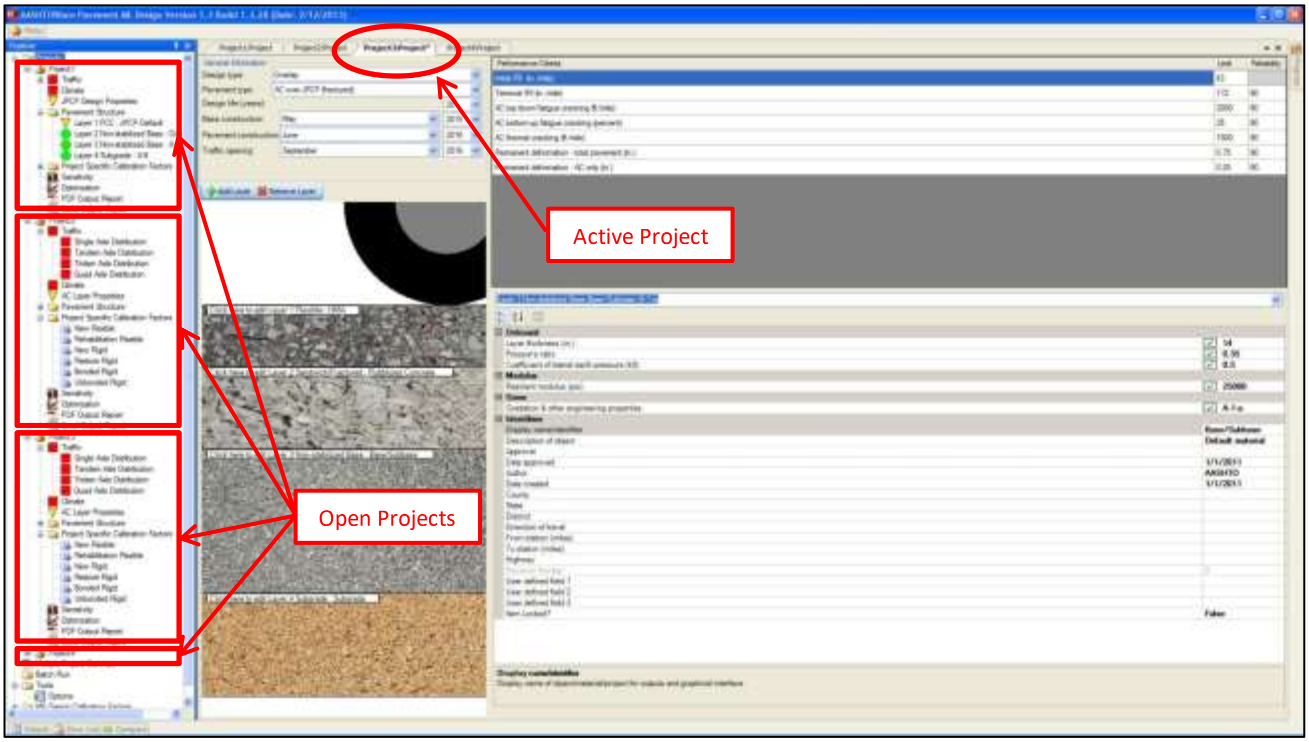



**Figure 2-9. Location of Open Projects**

There are four open projects (noted with boxes). Project 3 is the currently active project based on its tab being the highlighted one.

#### 2.6.2.1 – Folder Structure

The Explorer Pane has a tree structure containing folders and nodes. Some of these nodes have sub-nodes as indicated by a '+' symbol next to them. When the '+' symbol is clicked, the sub-nodes are revealed as seen in the two figures below. Clicking the '-' symbol will hide the sub-nodes.

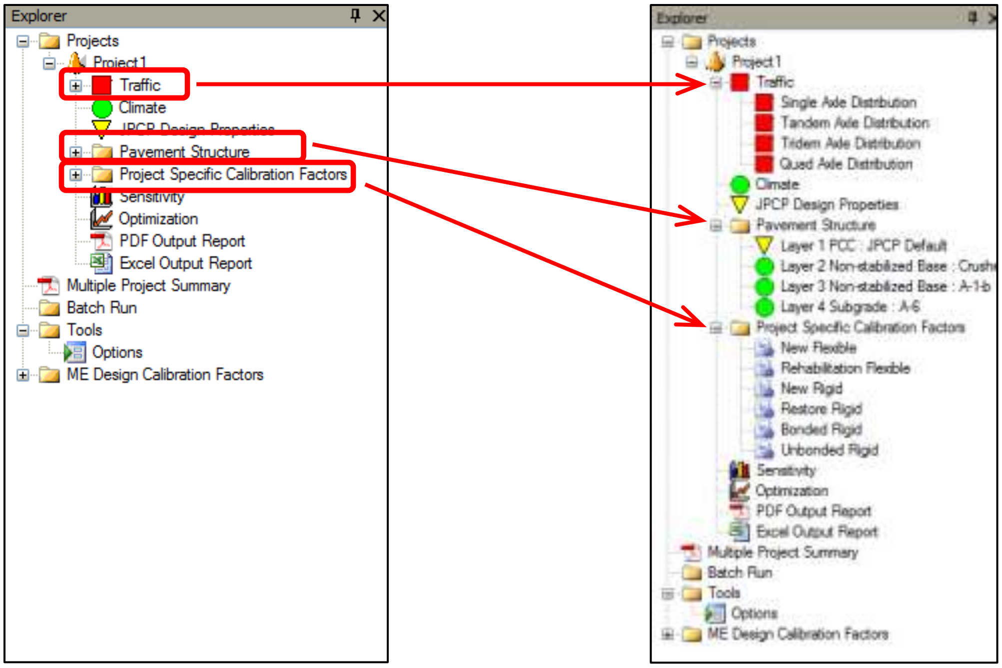



**Figure 2-10. Expanding Nodes**

### 2.6.2.2 – Projects Folder

All open projects will be under the 'Projects' folder. Multiple projects can be open at the same time. All project types will have the following common nodes:

- Traffic: Double clicking this will open the traffic inputs tab in the Project Tab Pane. Expanding this node will give access to the four axle load spectra nodes. Double clicking any of the axle load spectra nodes will open that spectra's inputs tab in the Project Tab Pane.
- Climate: Double clicking this will open the climate inputs tab in the Project Tab Pane.
- Pavement Structure: Contains the layers that have been added to the cross-section. Double clicking any of the layers will make it the active layer in the Project Grid area of the Project Tab Pane.
- Project Specific Calibration Factors: Contains the calibration factors for the project. Changes to the calibration factors in this area will affect that project only. Even though all of the calibration nodes are shown, the only one accessible for the project is the one appropriate for the design type (e.g., the 'New Flexible' calibration coefficient is the only node available for a reconstruct asphalt design).
- Sensitivity: Allows the user to examine the sensitivity of the project to specific inputs. Double clicking this node will open the sensitivity tab in the Project Tab Pane (see Section 2.6.2.5 – Sensitivity).
- Optimization: Allows the thickness optimization of any one layer above the bottom layer (which is assumed to be semi-infinite). Double clicking this node will open the optimization tab in the Project Tab Pane (see Section 2.6.2.6 – Optimization).

- PDF Output Report: Double clicking this node will open the PDF output report for the project if it has been run successfully. The PDF report can also be found in the output folder for the project. The output folder will be in the same location that the design file is saved in. The output report will have the same filename as the project filename (see Section 14.2.1 – PDF Report).
- Excel Output Report: Double clicking this node will open the Excel output report for the project if it has been run successfully (see Section 14.2.2 – Microsoft Excel Report). An Excel version of the output will only be produced if the setting for 'Generate Excel Reports?' in the Options tab (see Section 2.6.2.7 – Other Nodes below) is set to "True". The Excel output report can also be found in the output folder for the project. The output folder will be in the same location that the design file is saved in. The output report will have the same filename as the project filename.

There will be other nodes available for each project depending on the design type and pavement type. For example, asphalt projects will have an 'AC Layer Properties' node, concrete projects will have a 'Design Properties' node that is specific to whether it is a jointed plain concrete pavement (JPCP) or a continuously reinforced concrete pavement (CRCP), and rehabilitation designs will have a 'Backcalculation' node. Double clicking these nodes will bring up their inputs tab in the Project Tab Pane.

### 2.6.2.3 – Import/Export

Pavement layers, climate files, and traffic inputs can be exported and imported. Exporting of any of these nodes saves the input values to an XML formatted file (files will have an .xml extension). The import function will bring in input values from a previously saved XML file. To do either one, right click on the node and choose either 'Import' or 'Export', and then navigate to the folder/location to save to (in the case of export) or where the existing XML file is (in the case of import).

*WARNING: Exporting any one of the axle load spectra will export all four (single, tandem, tridem, and quad) into one file. Likewise, importing will import all four. So, make sure the XML file has data for all four so that the axle load spectra data is not overwritten with blanks. There is an option to import individual load spectra using the .alf file format. This is a file format that was used for the original MEPDG version of the software, and is still supported in Pavement ME Design. MDOT does not have load spectra in .alf format. Exporting to an .alf file is not supported in Pavement ME Design.*

If connected to the database, these items can also be imported from, and exported to, the database. 'Get from database' and 'Save to database' will be available options when right-clicking on a node.

### 2.6.2.4 – Project Node Color Scheme

Pavement ME Design uses a color scheme with the design nodes to make the user aware of where inputs may be required. An example is shown in Figure 2-11.

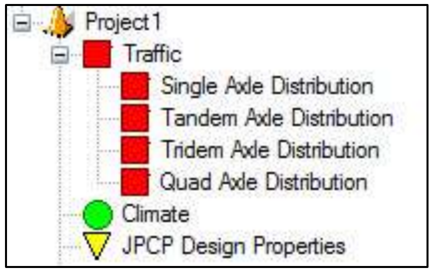



**Figure 2-11. Input Color Scheme**

- The <u>red square</u> indicates an area that is missing an input or requires the user to check the inputs. The design cannot be run if there are any red squares.
- The <u>yellow triangle</u> warns the user that, even though ME can be run with the inputs entered, the user has not looked at them to verify.
- The <u>green circle</u> indicates an area that the user has viewed.

*<u>WARNING</u>: A green circle is <u>not</u> an indication that the inputs are correct or appropriate.*

### 2.6.2.5 – Sensitivity

Double click 'Sensitivity' to open its tab in the Project Tab Pane. There will be a set of available inputs that depend on the design type and pavement type of the project. Click the box next to each input for which a sensitivity analysis is desired. A minimum value, maximum value, and increment value must be entered for each input selected for sensitivity as shown in Figure 2-12.

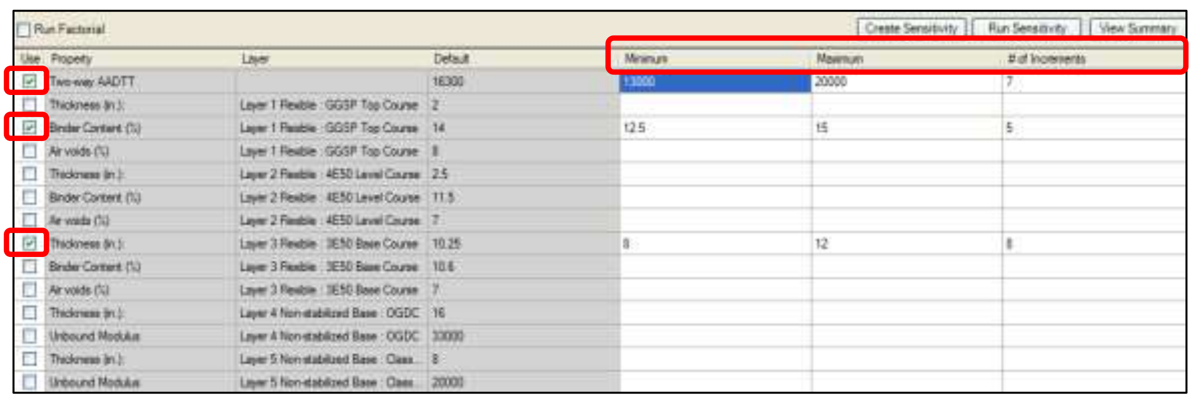



**Figure 2-12. Sensitivity Tab**

Boxes along the left side in the figure indicate inputs that have been selected to be included in the sensitivity analysis. An analysis will be run from the minimum value to the maximum value in equivalent segments defined by the '# of Increments' input. The number of values run will be one more than the value entered for '# of Increments'. The following illustrates how this works using the 'Two-Way AADTT' (average annual daily truck traffic) values entered in the figure above, and how it would look with only 2 increments.

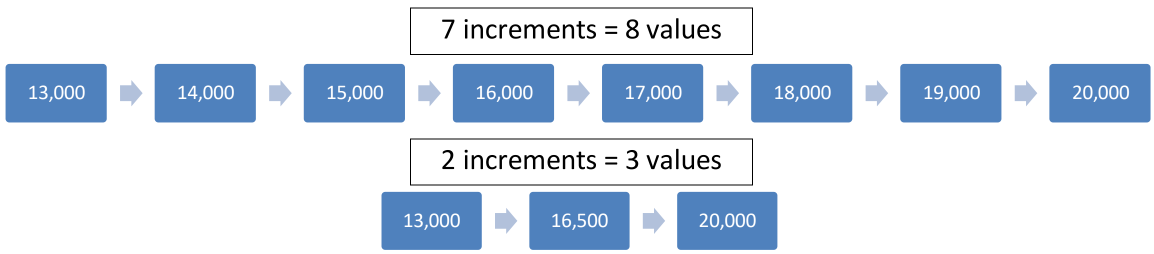



**Figure 2-13. Examples of Sensitivity Increments**

Before sensitivity can be run, a successful analysis must have been run on the project so that it can be used as the base case. Each input will be run separately unless the 'Run Factorial' box is checked. With a full factorial, all of the inputs are varied involving all the different combinations, resulting in many more analysis runs. The following example uses the values from the sensitivity tab figure above:

- <u>Without Factorial</u>: 8 runs varying two-way AADTT, 6 runs varying layer 1 binder content, and 9 runs varying layer 3 thickness for a total of 23 designs.
- <u>With Factorial</u>: All possible combinations using all three variables for a total of 432 designs (8 x 6 x 9).

*<u>WARNING</u>: Choosing to do a factorial with many inputs and increments can result in **very long** computation times.*

When the inputs, ranges, and increments for sensitivity have been chosen, the designs must be created. Do this by clicking the 'Create Sensitivity' button. A design will be created for each input value as specified by the range and increment as seen in Figure 2-14. After the designs have been created, the sensitivity can be run by clicking the 'Run Sensitivity' button. In Figure 2-14, three of the eleven sensitivity designs have been run successfully as indicated by the green circles. The yellow triangles indicate designs that are currently running or have yet to start. After the analysis is complete, the results can be viewed by clicking the 'View Summary' button.

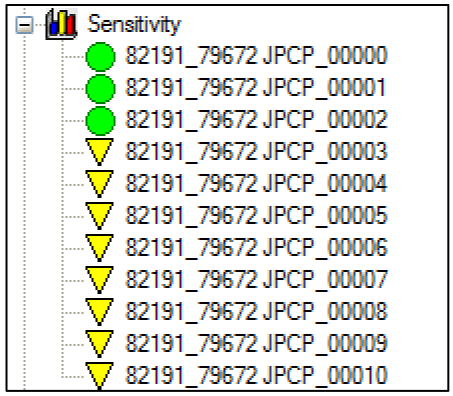



**Figure 2-14. Sensitivity Analysis Running**

All of these newly created sensitivity designs can be found in the 'Sensitivity' subfolder which will be in the same folder as the output from the original design, as seen in Figure 2-15. The output files from these sensitivity designs will be in the 'Sensitivity' subfolder under the folder for the project as seen below.

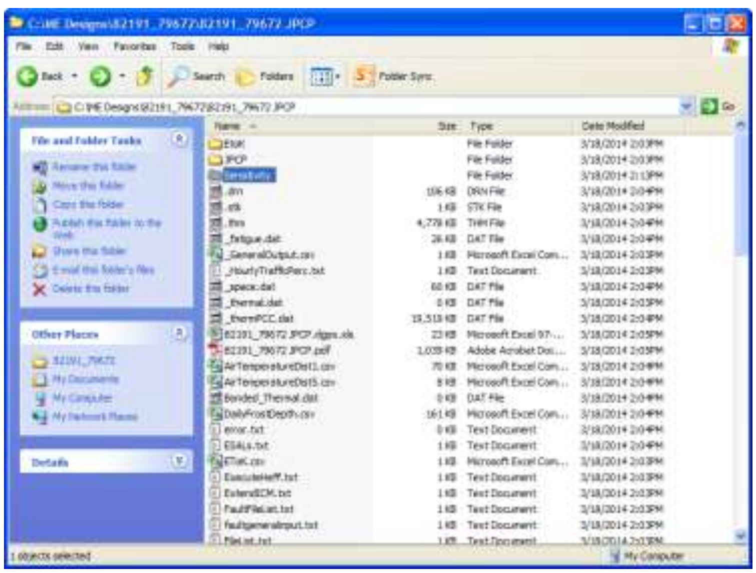


**Figure 2-15. Location of Sensitivity Results**

### 2.6.2.6 – Optimization

Optimization will find the lowest thickness for a single layer, within a user- specified range, that allows the design to pass all performance criteria. Only one layer can be optimized at a time, and Pavement ME Design will go no less than 0.5" increments. The following figure shows the optimization tab for a new JPCP design:

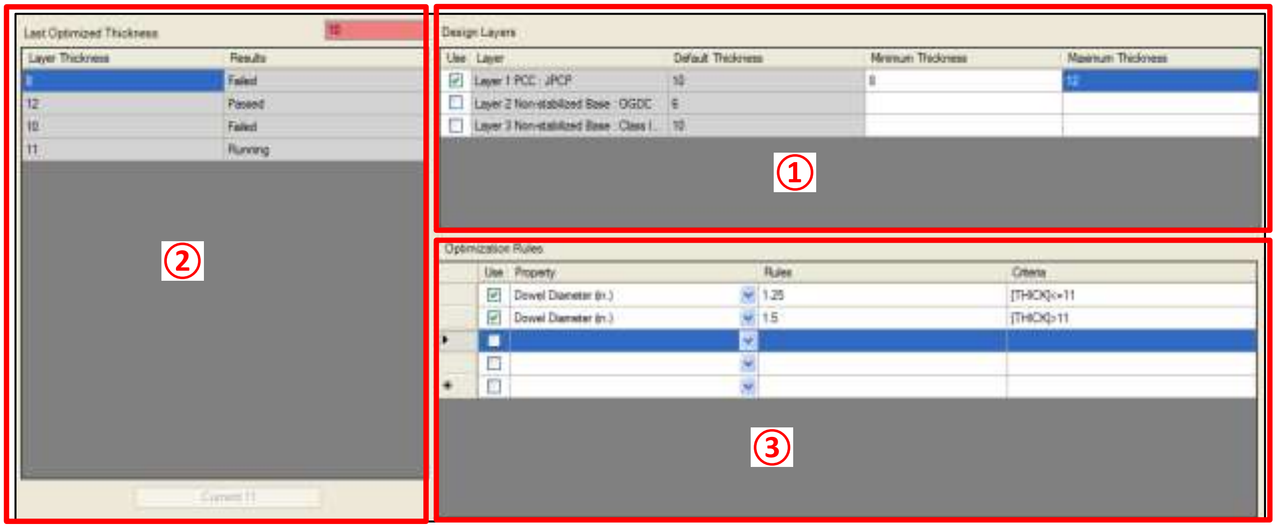



**Figure 2-16. Optimization Tab**

Optimization tab areas:

1. Layers that can be chosen for optimization. Only one can be selected. A minimum and maximum will need to be specified.
2. Shows the progression of the optimization process. Each thickness that has been run will be shown along with the result for each. The last thickness analyzed will be shown in the 'Last Optimized Thickness' box.
3. JPCP designs allow the use of optimization rules. These rules allow certain inputs to vary based on set conditions. For example, in the figure above, dowel bar diameter is varied based on the thickness of the concrete layer. These rules are only available with JPCP designs.

Figure 2-17 shows a flowchart of the optimization process.

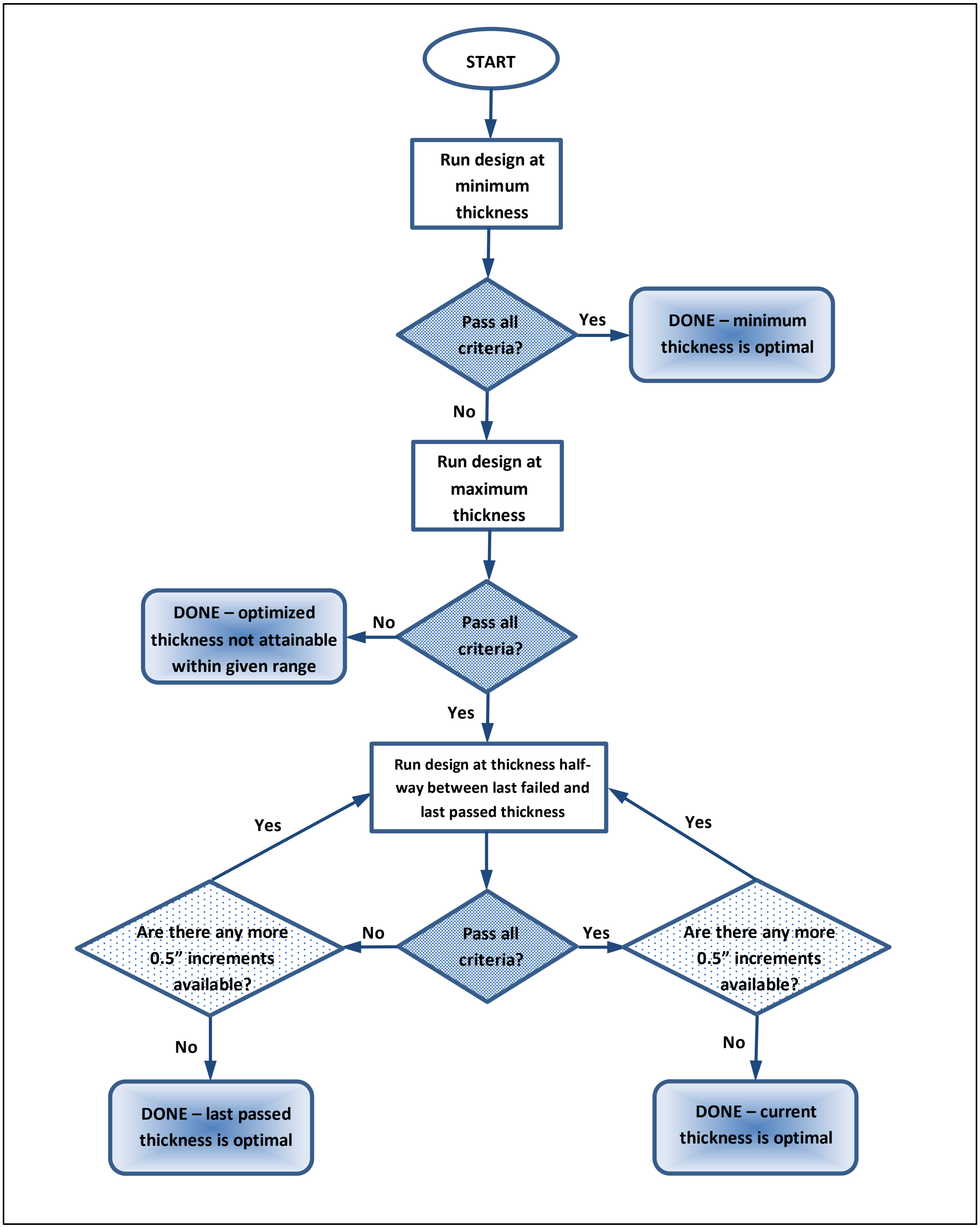



**Figure 2-17.  Optimization Flow Chart**

### 2.6.2.7 – Other Nodes

There are several other nodes in the Explorer Pane that are not project specific.

**Multiple Project Summary**

Double click this node to create a summary report for all projects open in the 'Projects' folder that have successfully run. This report will contain the first page of the PDF output report for each project.

**Batch Run Folder**

To run multiple projects in batch mode, right click the 'Batch Run' folder and select 'Load Projects'. Navigate to the location of the projects to select them. To select multiple projects within a folder, hold down the 'CTRL' key while clicking on each individual project you want to load. Click 'Open' when all the projects to be run have been selected. The 'Load Projects' command can be chosen as many times as needed to load projects files that are in different folders.

To remove a project from the batch list, right click the filename in the batch list and select 'Remove Project'.

*<u>WARNING</u>: Any individual projects that are open in the 'Projects' folder, cannot be loaded in the 'Batch Run' folder.*

When all projects to be run in batch mode have been loaded, the analysis can be started by right clicking the 'Batch Run' folder and selecting 'Run Batch Projects' or by selecting the 'Batch' button from the Menu Bar. As analysis of each project is completed, a green circle will appear in front of the project filename as seen in Figure 2-18.

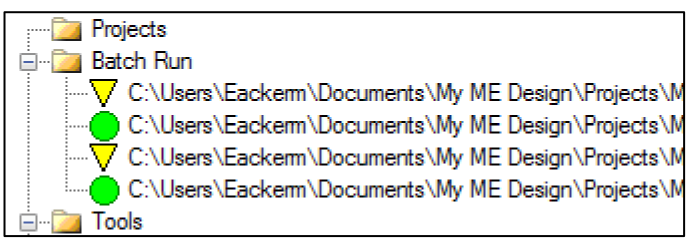



**Figure 2-18. Batch Files Running**

When the analyses are complete, the PDF output for each project can be viewed by double clicking each individual project's filename in the batch list. Alternatively, the first page of each project's PDF output report can be viewed in one summary report by right clicking the 'Batch Run' folder and selecting 'View Batch Report'.

**Tools Folder**

The tools folder contains the Options node. In addition, there will be several nodes that appear only when connected to the database as seen in Figures 2-19 and 2-20.


**Figure 2-19. Without Database Access**

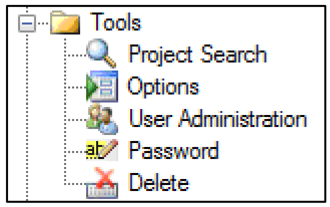



**Figure 2-20. With Database Access**

Double clicking the Options node will bring up the Options tab in the Project Tab Pane as shown below.

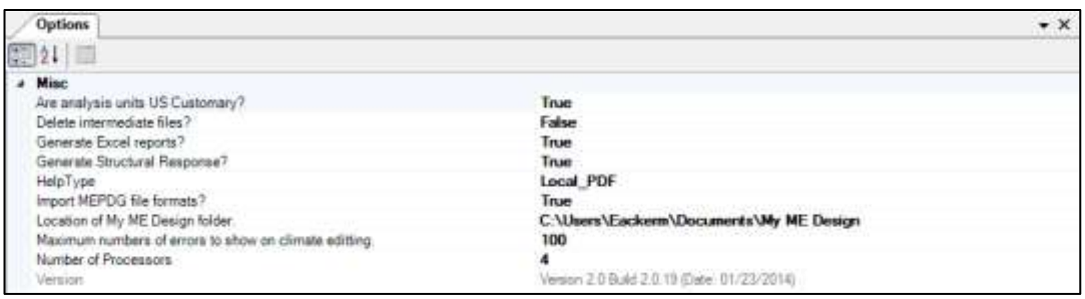



**Figure 2-21. Options Tab**

To change an option, click in the appropriate box to either access the drop-down menu of choices, or type in the appropriate value. The details on each option are:

- Are analysis units US Customary?: set to 'True' to use US Customary units, set to 'False' to use SI units.
- Delete intermediate files?: set to 'True' to have intermediate computational files deleted, set to 'False' to retain those files in the project output folder.
- Generate Excel reports?: set to 'True' to have Pavement ME Design generate an Excel output file in addition to the PDF output summary report, set to 'False' if an Excel output file is not desired.

- Generate Structural Response?: set to ‘True’ to have the pavement structural response saved in a file, set to ‘False’ if the structural response details are not desired.
- Help Type: set to ‘Local_PDF’ (suggested) to obtain help using the PDF help document, set to ‘Server_HTML’ to use an HTML based help document from the server (not currently set up), set to ‘Local_HTML’ to use an HTML based help document from the user’s computer (not currently set up).
- Import MEPDG file formats?: set to ‘True’ to be able to import projects created and saved in the MEPDG version of the software (files with a .mpd extension), set to ‘False’ if this is not desired.
- Location of My ME Design folder: specifies the default folder for saving Pavement ME Design files. Type in the location of the desired default location.
- Maximum numbers of errors to show on climate editing: specifies the maximum number of errors to show when editing the hourly climate data. 100 is more than enough – if there are more errors than that, then there are major problems with the climate file and it should undergo editing outside the Pavement ME Design environment.
- Number of Processors: displays the number of processors the user’s computer has. This will be the number of designs that can be run concurrently during a batch run (see Batch Run Folder section above). The value is automatically filled in with the value for the user’s computer when Pavement ME Design is installed. It can be edited, but it is not recommended do so.
- Version: displays the version number and the build date of Pavement ME Design. For information only – this cannot be edited.

When connected to the Pavement ME Design database, the following additional nodes will appear under the Tools folder:

- Project Search: provides a list of projects currently stored in the database (see Figure 2-22) that can be opened. Select the project of interest and click the ‘OK’ button to open the project. Information about the currently highlighted project can be found along the right side of the screen (prior to clicking ‘OK’).

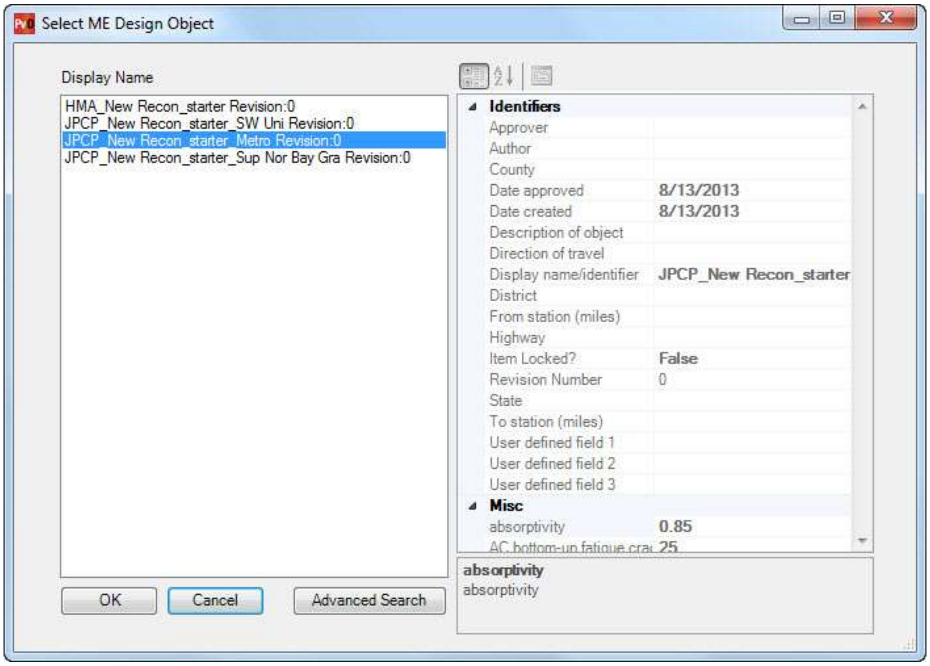



Figure 2-22. List of Files Available in the Database

To search for projects with specific values/inputs/properties, select the 'Advanced Search' button which will go to the following screen:

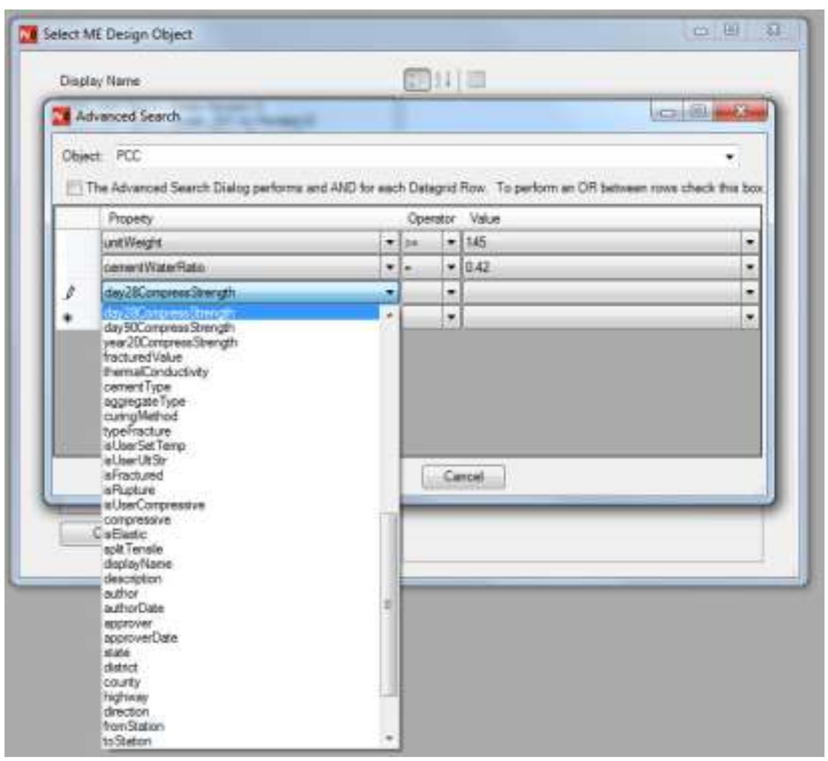



Figure 2-23. Database Search Dialog

The user can build a set of search terms based on one object (layer or other input parameters such as traffic). In the example above, the user wants to search for projects that have specific inputs in the Portland Cement Concrete (PCC) pavement layer. The list of properties that can be used in the search (drop-down list shown above), depends on what is chosen in the 'Object' drop-down.

- User Administrator: allows the software administrator to create and edit accounts for access to the database
- Password: allows the user to change their password for accessing the database
- Delete: allows the software administrator to delete information (projects, layers, etc.) in the database

### 2.6.3 – Progress Pane

The Progress Pane shows the progress of the analysis once a project, or batch of projects, has been started. Each stage of the analysis will be listed along with its percent completed. When running a batch of projects, each project will be listed separately as it is running (see Section 2.6.2.7 – Other Nodes for information on batch analysis).

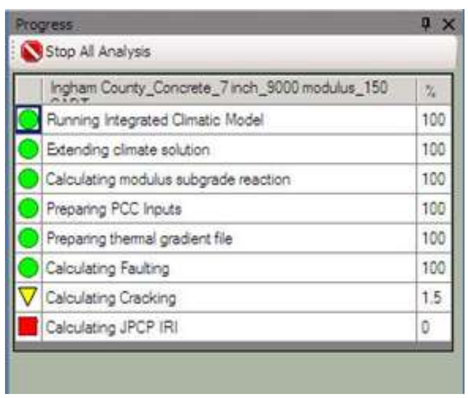



**Figure 2-24. Progress Pane**

### 2.6.4 – Project Tab Pane

The Project Tab Pane represents the area where data entry will take place. It contains several zones as noted in Figure 2-25.

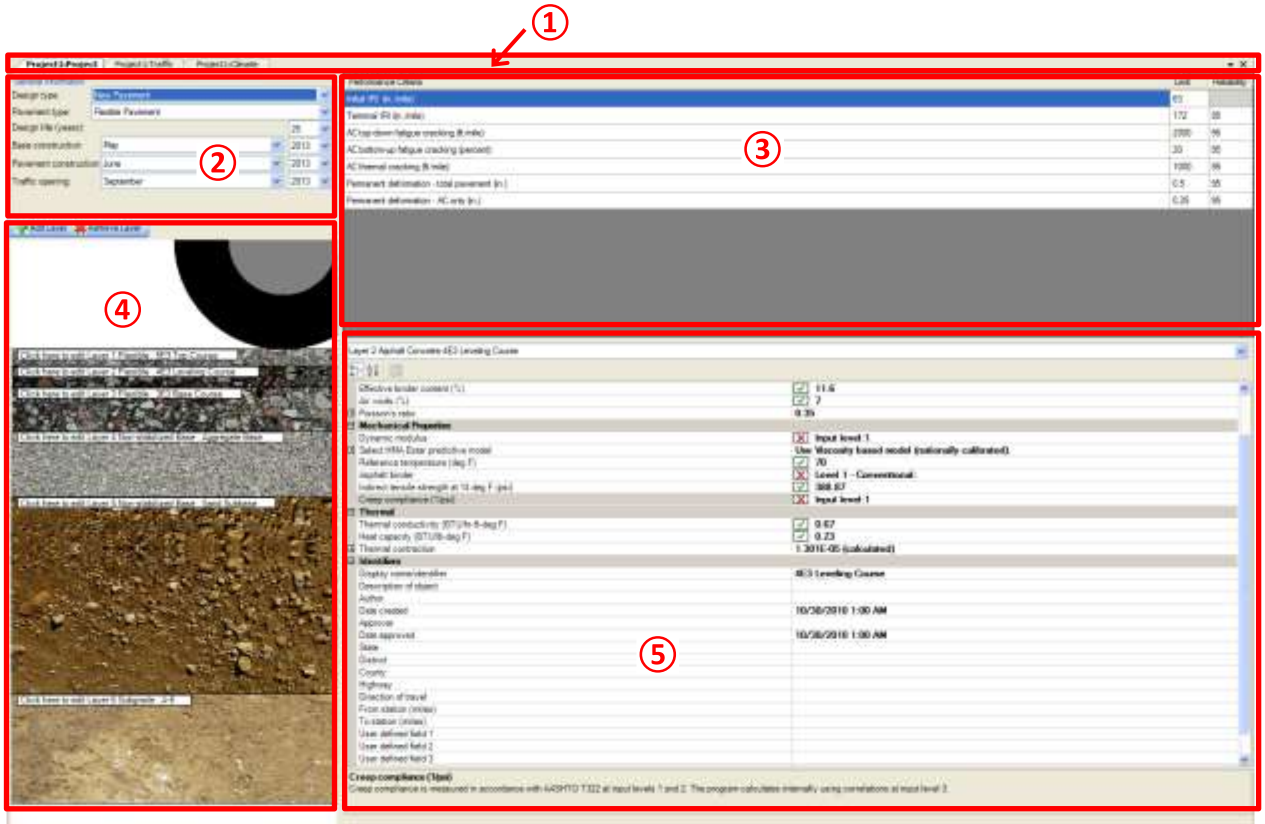



**Figure 2-25. Project Tab Pane Zones**

Project tab pane zones:

1. Tabs
2. General Project Information
3. Performance Criteria
4. Pavement Structure
5. Property Grid

### 2.6.4.1 – Tabs

The tabs that open can be seen at the top of the Project Tab Pane. Tabs from multiple projects can be open at one time. The active tab will be highlighted white. This will be the tab that is closed if the ‘x’ button is clicked (circled below).


**Figure 2-26. Closing a Tab**

These project tabs can be unpinned so that they are free floating on the screen. See Section 2.7 – Screen Customization for more information on unpinning and docking tabs.

### 2.6.4.2 – General Project Information

The General Project Information area is where the design begins. The other areas of the pane will not be populated until the 'Design Type' and 'Pavement Type' inputs have been chosen. There are three choices for 'Design Type': New Pavement, Overlay, and Restoration. Once the 'Design Type' has been chosen, the 'Pavement Type' drop-down will populate. An example of the choices for Overlay can be seen in Figure2-27.

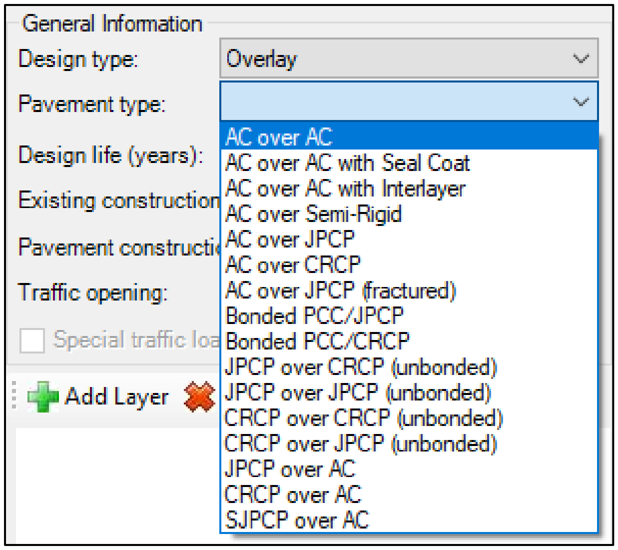



**Figure 2-27. General Project Information Entry**

Other items to be chosen in this area are Design Life, the month and year of construction of certain key pavement layers, the month and year the project will be opened to traffic and a checkbox for running an analysis using special traffic loadings.

The special traffic loading checkbox will only be available for asphalt designs. It allows for a design to be run using one unique axle configuration/load only. When selected, traffic inputs will be in the Property Grid area instead of as a separate tab, as shown in Figure 2-28.

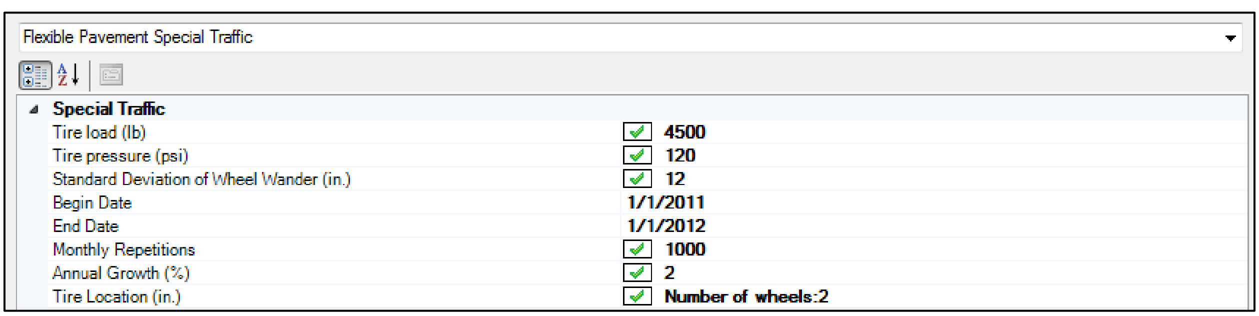



**Figure 2-28. Special Traffic Loading Inputs**

### 2.6.4.3 – Performance Criteria

This area will populate with the performance criteria (distresses) that will be predicted over the design life. The types of criteria will depend on the design type/pavement type chosen. The criteria for asphalt, JPCP, and CRCP designs are:

- Asphalt designs: International Roughness Index (IRI), fatigue (bottom-up) cracking, longitudinal (top-down) cracking, transverse (thermal) cracking, total rutting, asphalt layer rutting
- JPCP designs: IRI, % slabs cracked, faulting
- CRCP designs: IRI, punchouts

For asphalt overlays, reflective cracking is another criteria that is predicted. In addition, post-overlay cracking in the underlying JPCP or punchouts in the underlying CRCP, will be predicted for asphalt overlays.

Each performance criteria requires a 'Limit' and 'Reliability' value to be entered. The 'Limit' represents the maximum value allowed at the end of the design life. Reliability is the probability that the performance criteria will be less than the value entered for 'Limit' over the design life entered. For example, reliability of 90 would indicate the desire that there is a 90% chance (or 90 out of every 100 projects built) that the distress will not exceed the limit value entered during the design life. Conversely, this also means that there would be a 10% chance that the distress will exceed the limit value.

In addition, the Initial IRI value needs to be entered. The predicted IRI will start from this point and increase over the design life. See Chapter 5 – Performance Criteria and Reliability for distress thresholds and reliability values.

### 2.6.4.4 – Pavement Structure

This area contains a visual representation of the entered cross-section. Clicking on a layer will bring its properties up in the Property Grid area. Some layers will be automatically added when the design type and pavement type are chosen. The last layer will always be assumed to be semi-infinite and thus, does not require a thickness to be entered.

Clicking on the tire will bring up the traffic tab. Clicking on the empty space above the pavement and to the left of the tire, will bring up the climate tab.

At the top of this area are the Add Layer and Remove Layer buttons. Select the Add Layer button to add a layer to the cross-section. The Add Layer dialog box will appear as seen in Figure 2-29.

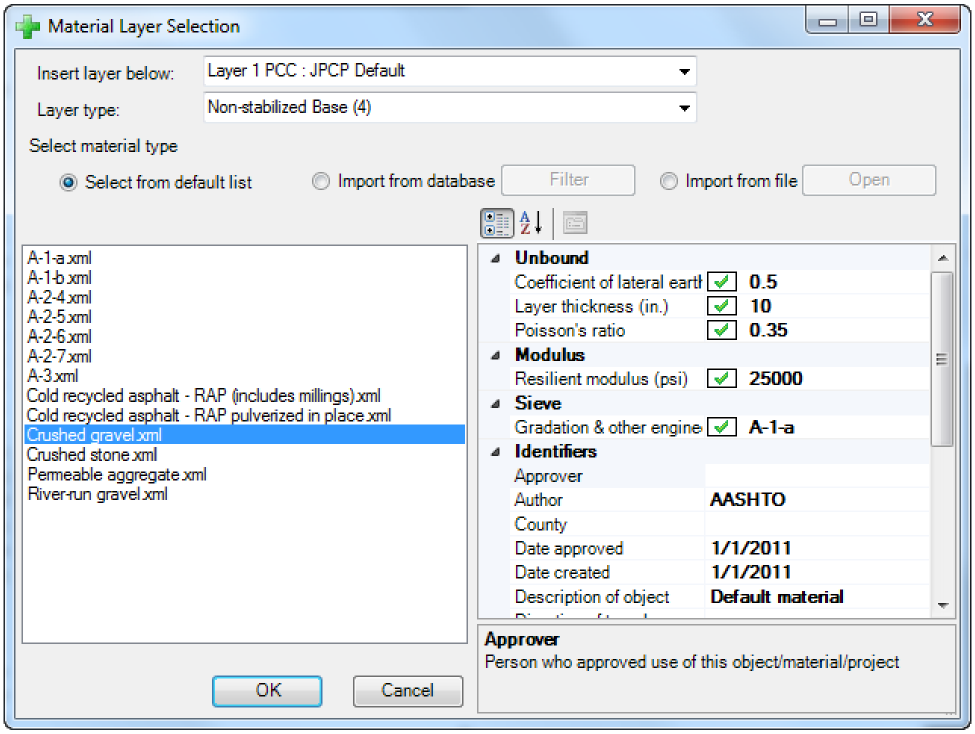



**Figure 2-29. Add Layer Dialog Box**

The details on the Add Layer dialog box are:

- Insert layer below: provides a list of existing layers in the cross-section. Choose the layer that the new layer should go directly under.
- Layer Type: provides a list of layer types as follows: PCC, Flexible, Chemically Stabilized, Sandwiched Granular, Non-stabilized Base, Subgrade, and Bedrock. Choose the appropriate layer type.
- Location: three radio buttons provide locations from which to choose the correct layer:
    - Select from default list: default layers that are stored in the AASHTOWare/ME Design defaults folder on the user's computer
    - Import from database: allows selection of the layer from those saved in the database (only available when connected to the database)
    - Import from file: allows selection of the layer from a saved design file
- Lower left box: lists the layers stored in the AASHTOWare/ME Design defaults folder when using the default list location option, the layers stored in the database when using the import from database option, or the layers that can be used from a saved Pavement ME Design file when using the import from file option
- Lower right box: lists the inputs for the layer selected in the left box. Changes to these inputs can be made in this box prior to inserting the layer in the cross-section.

When using the import from file option, click the 'Open' button to get a dialogue box that allows navigation to the location of the correct design file. Select the design which contains the layer to be inserted and click 'Open'. The available layers in the saved design file that match the layer type chosen will be displayed in the left box.

Click 'OK' to insert the chosen layer into the cross-section with the displayed inputs (inputs can be still be changed in the Property Grid area later if needed).

To remove a layer, click the 'Remove Layer' button. A dialogue box will appear listing all the current layers in the cross-section. Click the layer to be removed, and click the 'OK' button. Alternatively, a layer can also be removed by right-clicking it in the Pavement Structure diagram and selecting 'Delete'.

### 2.6.4.5 – Property Grid

The Property Grid area displays the properties (inputs) for the currently selected layer. Other properties such as Project Identifiers, JPCP Design Properties, AC Layer Properties, and calibration coefficients can be displayed here as well. There are three ways to change to another layer to see its properties:

- Select the layer of interest in the drop-down menu at the top of the Property Grid area
- Single click the pavement layer in the Pavement Structure diagram
- Double-click the layer in the Explorer Pane

Below the layer properties for each layer, is a section called Identifiers. The Display Name/Identifier entry is the name that will appear for that layer in the Pavement Structure diagram and the Explorer Pane. If the name is changed, click on a different pavement layer in the Pavement Structure diagram to change the name shown in that area. Double-clicking the existing layer name in the Explorer Pane will change the name displayed in that area. The remainders of the entries are pieces of information that will be stored in the database, if the layer is saved to the database. The layer can be located later from the database by searching on any of the terms entered in this area.

At the very bottom of this area is a help box that will give a little info on the currently selected attribute. Clicking on any of inputs will provide a brief description of the input and range of values the software will accept. For example, clicking on the PCC coefficient of thermal expansion input in the PCC layer, yields the following in this box:

**PCC coefficient of thermal expansion (in./in./deg F x 10^-6)**
Coefficient of thermal expansion (CTE) of PCC materials. Can be a positive (increase in length) or negative (decrease in length) value.
Minimum:2
Maximum:8

**Figure 2-30. Help Box**

**Entering Properties**

Different properties require different methods for entering the value. The 'JPCP Design Properties' can be used as an example of these different methods. The 'PCC surface shortwave absorptivity', 'PCC joint spacing', and 'Erodibility index' inputs will be used for this example as shown in Figure 2-31.

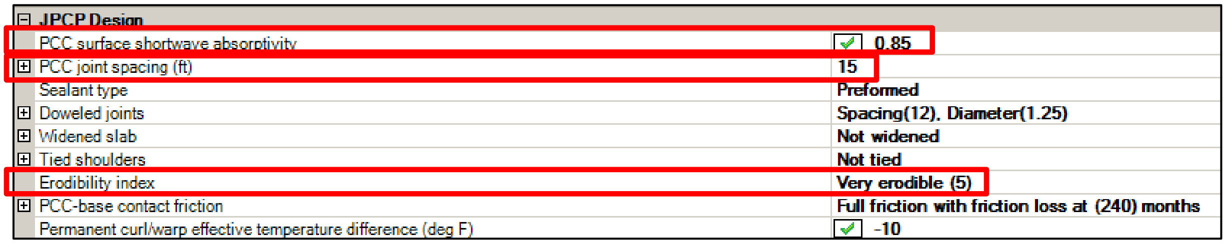



**Figure 2-31. Example of Different Input Methods**

<u>Single Value - Direct Entry</u>

For 'PCC surface shortwave absorptivity', the value can be entered directly in the box. Click in the box and enter the new value.


**Figure 2-32. Single Value Entry Example**

<u>Multiple Values Required</u>

For 'PCC joint spacing', there are additional choices as indicated by the triangle (▷) symbol on the left side. Click the symbol for access to the area for entering the needed values. In this case, the first needed input is a true/false question on if there is random joint spacing. Depending on the answer to that question, the joint spacing value (or values in the case of random), are entered. For this example, we expect the joints to be the same distance, so "FALSE" is chosen for the random spacing question, and the distance value is entered in the 'Joint Spacing' box. The new value will be reflected in the 'PCC joint spacing' box after the user has left this entry box or clicks the triangle (▷).

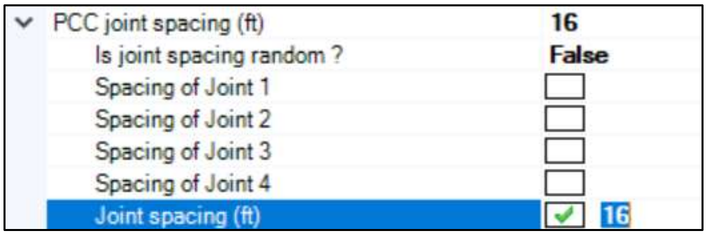



**Figure 2-33. Multiple Value Entry Example**

Drop-Down

Some inputs will present the user with a drop-down arrow after clicking in the box. Selecting the drop-down arrow will provide the opportunity to enter the value. The user may be presented with a list of pre-set choices, a list of additional inputs that can be entered, or a table of inputs. In the case of 'Erodibility index', a list of five choices is provided for the user to select from.

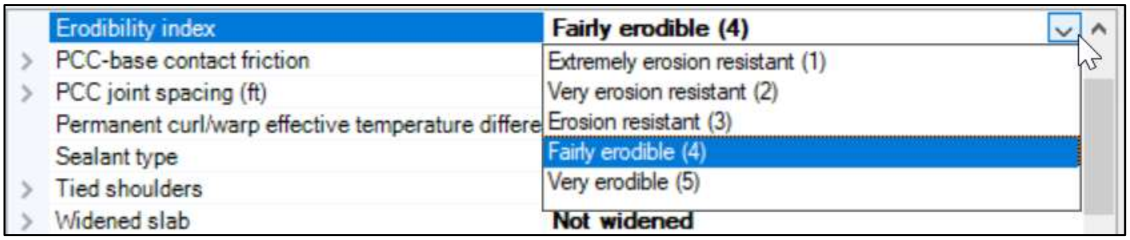



**Figure 2-34. Drop-Down Entry Example**

When a value has been entered, a green check mark is placed next to the input. If no value is entered, an X will appear and the project cannot be run. Figure 2-35 shows an example of an asphalt layer with some missing inputs. The 'Creep Compliance' drop-down shows how the values have not been entered yet. 'Dynamic modulus' and 'Asphalt binder' are also missing.

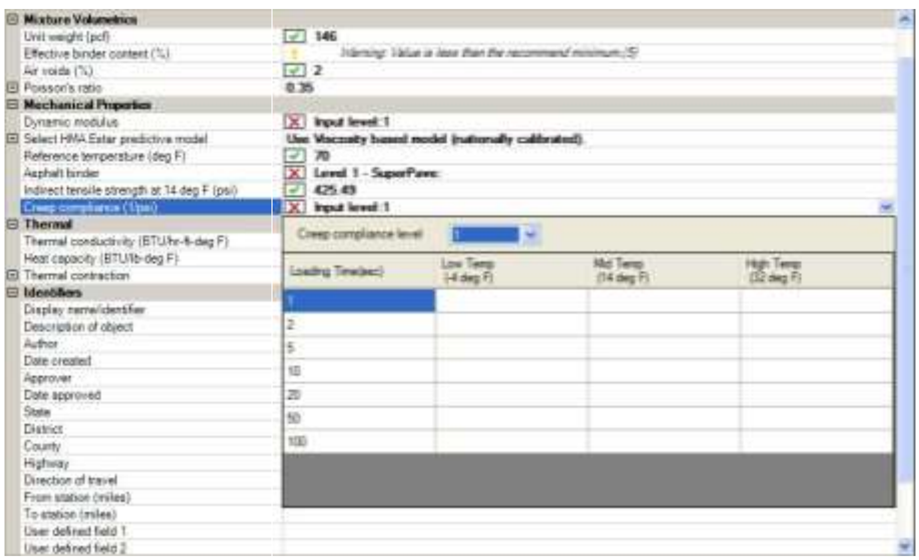



**Figure 2-35. Example of Missing Inputs**

The yellow exclamation point and warning message for the 'Effective binder content' input in Figure 2-35 indicates a value that is outside an expected range for that input. This is strictly a warning to the user and will not prevent the project from being analyzed. Clicking in the box will reveal the value that has been entered.

### 2.6.5 – Output/Error List/Compare Pane

This pane contains the Output Tab, Error List Tab, and Compare Tab. Each is described below.

#### 2.6.5.1 – Output Tab

When an analysis is running, the results of each stage and any errors or problems, will be displayed in this tab. The time the analysis started and was completed is displayed, so this is a good way to see how long the analysis took. If the analysis encounters a problem and does not complete properly, look in this pane to see if an error is displayed. This may help in correcting the problem and obtaining a completed analysis. An example is shown in the following figure.

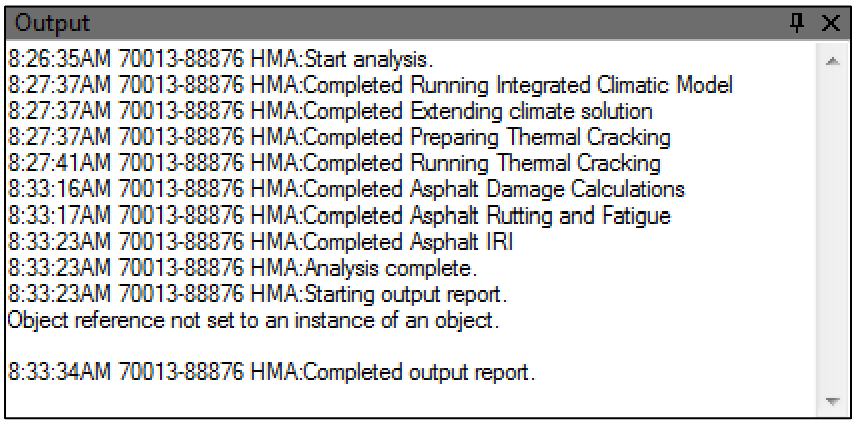



**Figure 2-36. Output Tab**

#### 2.6.5.2 – Error List Tab

The error list tab will show any errors in the current design that will not allow the analysis to run. If a message is received that errors must be corrected before the analysis can be run, check this tab to see what they are. An example is shown in Figure 2-37.

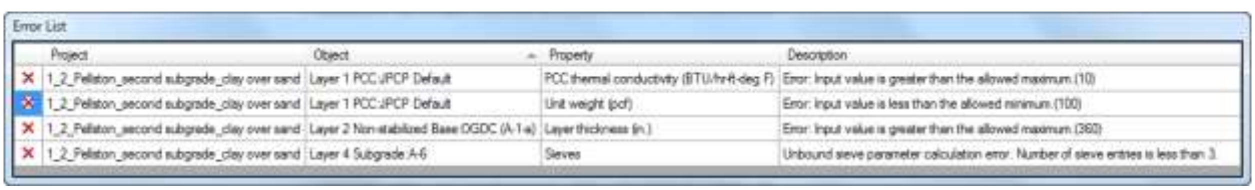



**Figure 2-37. Error List Tab**

### 2.6.5.3 – Compare Tab

The Compare tab allows two currently open projects to be compared to see what differences exist between them. Both projects must be open in the software to use this function. To compare two projects, open the Compare tab and select the desired projects from the drop-downs to the left and right of "Compare To" as shown in Figure 2-38. All projects currently open will be listed in the drop-downs.

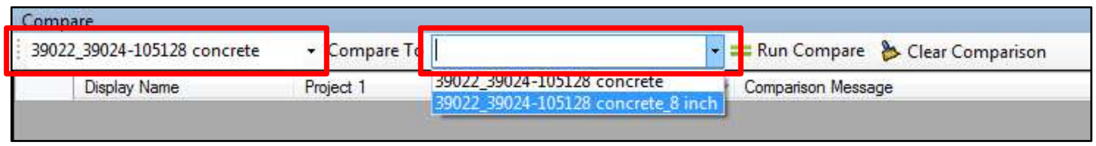



**Figure 2-38. Compare Tab**

Click the 'Run Compare' button to run the Comparison. A list of items that differ between the two projects will appear as shown in Figure 2-39.

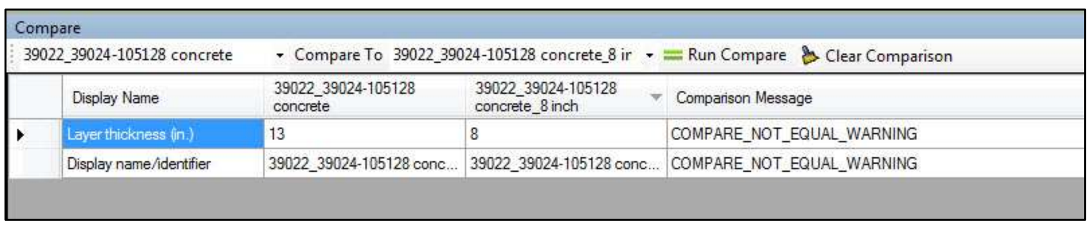



**Figure 2-39. Comparison Results**

*<u>WARNING</u>: The list of differences can get very large for projects that vary significantly. Items such as project identifiers and inputs involving large tables of inputs (such as axle load spectra and asphalt dynamic modulus) will list every value if they are different.*

## 2.7 – Screen Customization

The look of the Pavement ME Design window can be customized by undocking panes, unpinning them so they hide, or moving them to different locations. An example of a customized screen can be seen in Figure 2-40. In this case, the Menu Bar, Progress Pane, and Output/Error/Comparison Pane are hidden because they have been unpinned. This gives more screen space to the Explorer and Project Tab panes.

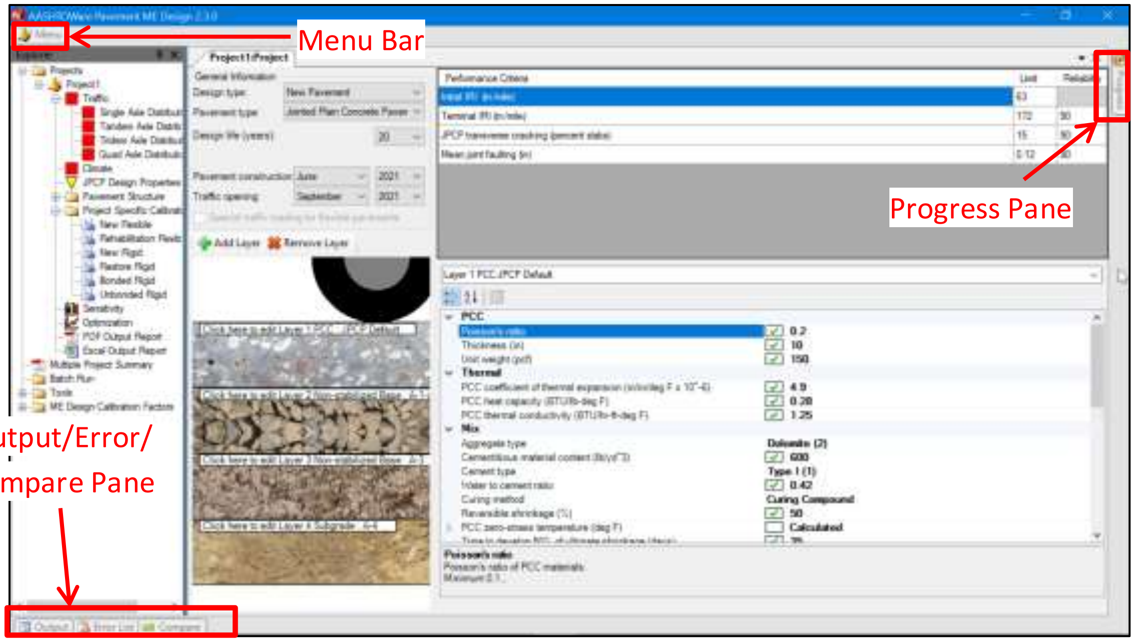



**Figure 2-40. Example of Unpinning Panes**

Undocking

Panes and tabs can be made to be "free-floating" anywhere on the screen by undocking them. To undock, grab the pane/tab header area by clicking and holding the left mouse button. Drag it to the desired location and release the mouse button. The pane/tab will become a separate box that can be resized by grabbing the corners. In Figure 2-41, the Output/Error List/Compare Pane has been undocked and moved to the lower left area of the window.

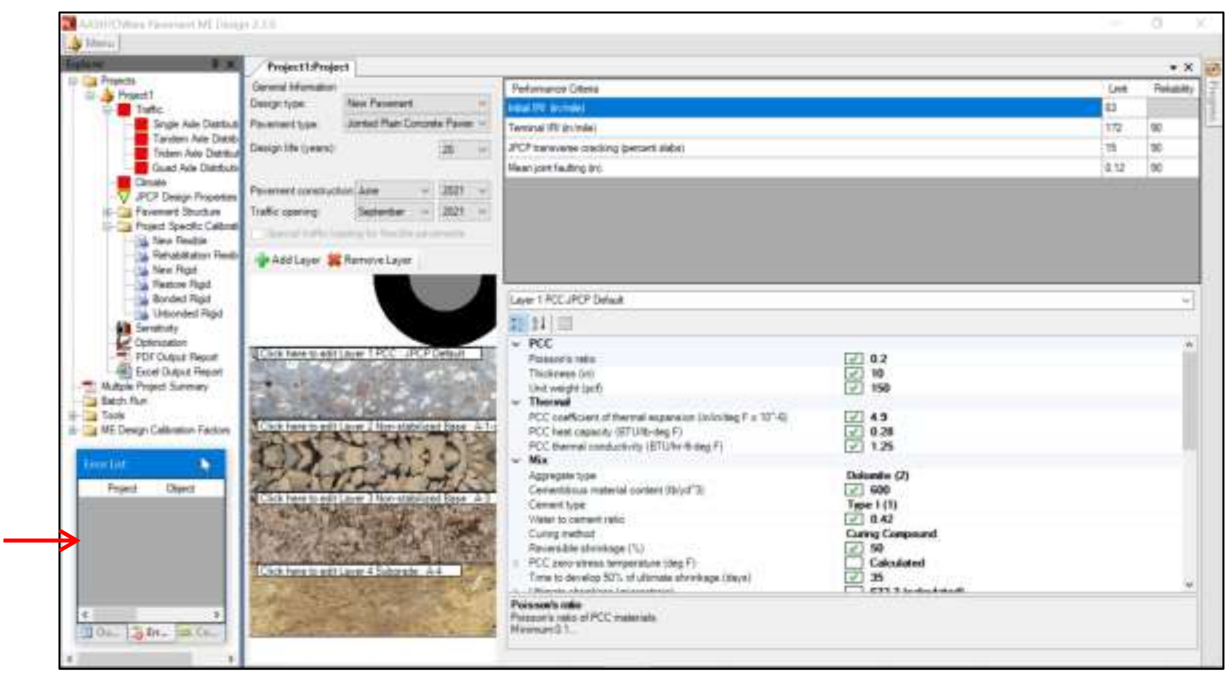


**Figure 2-41. Output/Error List/Compare Pane Has Been Undocked**

Unpinning (Auto-Hide)

Panes that are unpinned, will hide when they are not active. To pin or unpin a pane, click the button with the shape of a pin on the pane's header, as seen in the figure below. When the pin is vertical, the pane will remain in place. When the pin is horizontal, it will hide when not active.

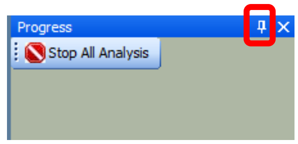



**Figure 2-42. Location of Symbol for Pinning/Unpinning**

When hidden, a tab will indicate the location of the pane as shown in Figure 2-43. Hovering the cursor over the tab will unhide the pane temporarily until the cursor is moved away from the pane. Clicking the tab will open the pane until an area outside the pane is clicked.

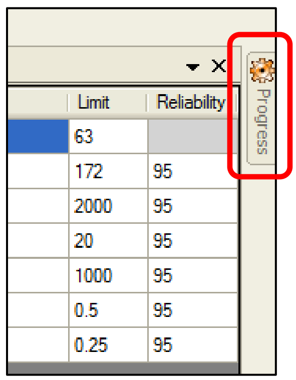



**Figure 2-43. Unpinned Pane in Hidden Mode**

Moving

Panes can be docked in other areas of the screen, or within other panes. To do this, grab the pane's header area by clicking and holding the left mouse button. Drag the pane toward an edge of the screen, if that edge is available for docking, the docking symbol will appear similar to the one shown in Figure 2-44.

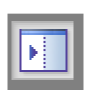


**Figure 2-44. Single Docking Symbol**

This particular symbol indicates that the right edge is available to dock the pane. Similar symbols for the other edges will appear if a pane is not already docked there. Panes and project tabs can also be docked within other panes. Dragging the pane over another pane will produce the following set of docking symbols.

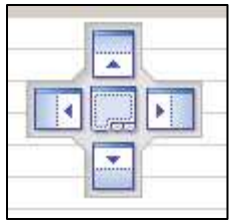


**Figure 2-45.  Full Docking Symbol**

Place the cursor over the symbol for the edge you want to dock to and release the mouse.  The symbol in the center will dock it directly with the existing pane being hovered over, resulting in tabs for each pane. The tabs in the Output/Error List/Compare Pane and the project tabs in the Project Tab Pane are examples of this.

# Chapter 3 – Design Process

## 3.1 – Pavement Design Steps

The following is general guidance on the steps necessary to produce a pavement design. Not all projects or design types will follow this general process. Details on each of these steps follow the list.

Preparation

1. Gather together data sources and determine what is yet needed. Initiate any investigations, particularly any field work that is weather dependent and may take much longer to conduct.
2. Obtain traffic information from Statewide Transportation Planning Division
3. Create initial trial design with DARWin 3.1 (AASHTO 1993 method)

Using Pavement ME Design

4. Initiate design in Pavement ME Design by opening a starter file of the design type for the project
5. Verify design life, performance criteria, and reliabilities are correct
6. Enter traffic information based on recommendations from Statewide Transportation Planning Division
7. Choose climate station
8. Add/delete layers as needed and change appropriate material inputs. This includes determination of any project specific design elements such as widened slab or base stabilization.
9. Review all layers and inputs to ensure they are correct
10. Run the initial trial design
11. Examine the summary output and results to assess whether the trial design has met the criteria for accepting the design
12. If the design is not acceptable, revise the trial design and re-run until an acceptable design is found

Post-Design

13. Submit for QA check
14. Report final accepted design

### 3.1.1 – Step 1: Gathering Data

Prior to the design being created, certain information may be required. This information may vary depending on whether it is a new/reconstruct design or a rehabilitation design. Examples of information that may be needed include the following:

- Subgrade soil resilient modulus from soil identification through soil borings and/or from falling weight deflectometer (FWD) backcalculation.
- Include information on the water table depth determined from soil borings.
- Sampling of the sand subbase for new/reconstruct projects to determine if it can be re-used.
- Site specific traffic study requests.
- For rehabilitation projects, a site survey may be needed for a condition assessment of the existing pavement (see Chapter 13 – Existing Layer Inputs for Rehab Design). Cores may be needed to determine the existing pavement thickness.
- FWD testing for backcalculated pavement layer moduli used in rehabilitation designs.

Some of these, such as FWD testing and traffic studies, are weather dependent and may take several months to complete. Therefore, it is suggested that these types of items be considered well in advance of needing to complete the pavement design.

### 3.1.2 – Step 2: Request Traffic Information

A Traffic Analysis Request (TAR) should be requested using Form 1730. This request may take up to 30 days to complete, so submit the request at least this amount of time before the results are needed. Check the 'Equivalent Single Axle Loadings (ESALs)' and 'M-E Inputs for Pavement Design' boxes to obtain the traffic inputs necessary for ME pavement design. The TAR form can be found in the forms repository in the MDOT intranet (internal website).

### 3.1.3 – Step 3: Create Initial Trial Design

Create the initial design using the DARWin 3.1 program. Use the ESAL information provided by Statewide Transportation Planning, the appropriate AASHTO 1993 resilient modulus for the subgrade type, and other typical inputs listed in Appendix A.

### 3.1.4 – Step 4:  Initiate Design in Pavement ME Design

Begin the design in Pavement ME Design by opening the starter design file for the type of design (concrete reconstruct, asphalt reconstruct, unbonded concrete overlay, etc.).  The starter design files are on the Construction Field Services Division common server in the 'ME Pvmt Design' folder.  This folder is only accessible to pavement design personnel.  After opening the appropriate starter design file, save this file to your computer before making modifications.  When naming the save file, do not use special characters (i.e. semicolon).

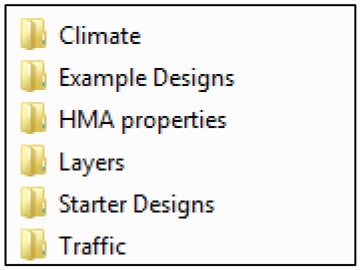



**Figure 3-1.  Folders in the 'ME Pvmt Design' Folder**

### 3.1.5 – Step 5:  Enter General Design Information

Verify that the inputs in the General Information and Performance Criteria are correct.  Appropriate values can be found in Chapters 4 and 5.

### 3.1.6 – Step 6:  Enter Traffic Information

Using the traffic memo from Statewide Transportation Planning, enter the correct traffic information.  The memo will recommend a specific weigh-in-motion site, classification site, cluster (see Section 7.3 – Traffic Cluster Method), or statewide freeway or non-freeway average be used.  Import the recommended traffic and axle load distribution .XML files based on what is recommended in the memo.  These files can be found on the Construction Field Services Division common server in the 'ME Pvmt Design\Traffic' subfolder.  This folder is only accessible to pavement design personnel.  The axle load distribution filenames start with "ALS" while the traffic filenames start with "Traffic".  Cluster values are copied and pasted into the traffic and axle load distribution tabs from the Excel file 'Level 2B ME Inputs.xlsx'.  This Excel file is in the same Traffic subfolder noted above.  Each traffic input that requires more than a single value (titles highlighted in Figures 3-2 and 3-3) is included in the same 'INPUTS' tab of the spreadsheet as shown in Figure 3-4.  Details on traffic inputs, and importing the .XML files, can be found in Chapter 7 – Traffic Inputs.

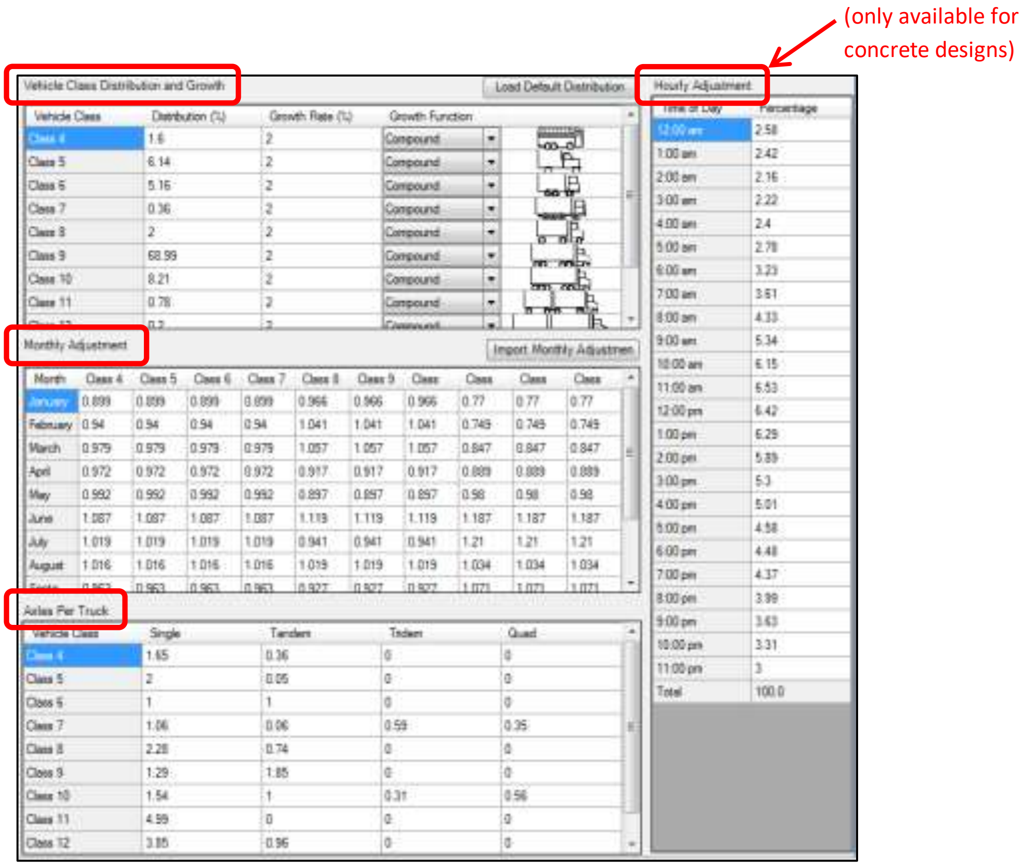



**Figure 3-2. Traffic Inputs with More Than a Single Value**

| 82131_76903 JPCP:Single | 82131_76903 JPCP:Tandem | 82131_76903 JPCP:Tridem | 82131_76903 JPCP:Quad | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | Class | Total | 3000 | 4000 | 5000 | 6000 | 7000 | 8000 | 9000 | 10000 | 11000 |
| January | 4 | 100 | 0.19 | 0.22 | 0.48 | 1.65 | 3.15 | 7.91 | 8.85 | 12.59 | 11.91 |
| January | 5 | 100 | 2.63 | 15.77 | 17.16 | 15.08 | 8.65 | 9.15 | 5.93 | 5.89 | 4.38 |
| January | 6 | 100 | 0.33 | 0.88 | 1.22 | 1.81 | 2.18 | 5.14 | 7.38 | 13.84 | 16.11 |
| January | 7 | 100 | 2.19 | 1.74 | 1.77 | 2.23 | 1.91 | 2.65 | 2.87 | 4.35 | 5.04 |
| January | 8 | 100 | 1.56 | 2.15 | 3.32 | 5.07 | 6.18 | 10.68 | 11.56 | 14.11 | 9.46 |
| January | 9 | 100 | 1.42 | 2.76 | 2.48 | 2.88 | 2.47 | 4.72 | 7.33 | 16.74 | 20.72 |

**Figure 3-3. Axle Load Distribution Inputs (Only a Portion Shown)**

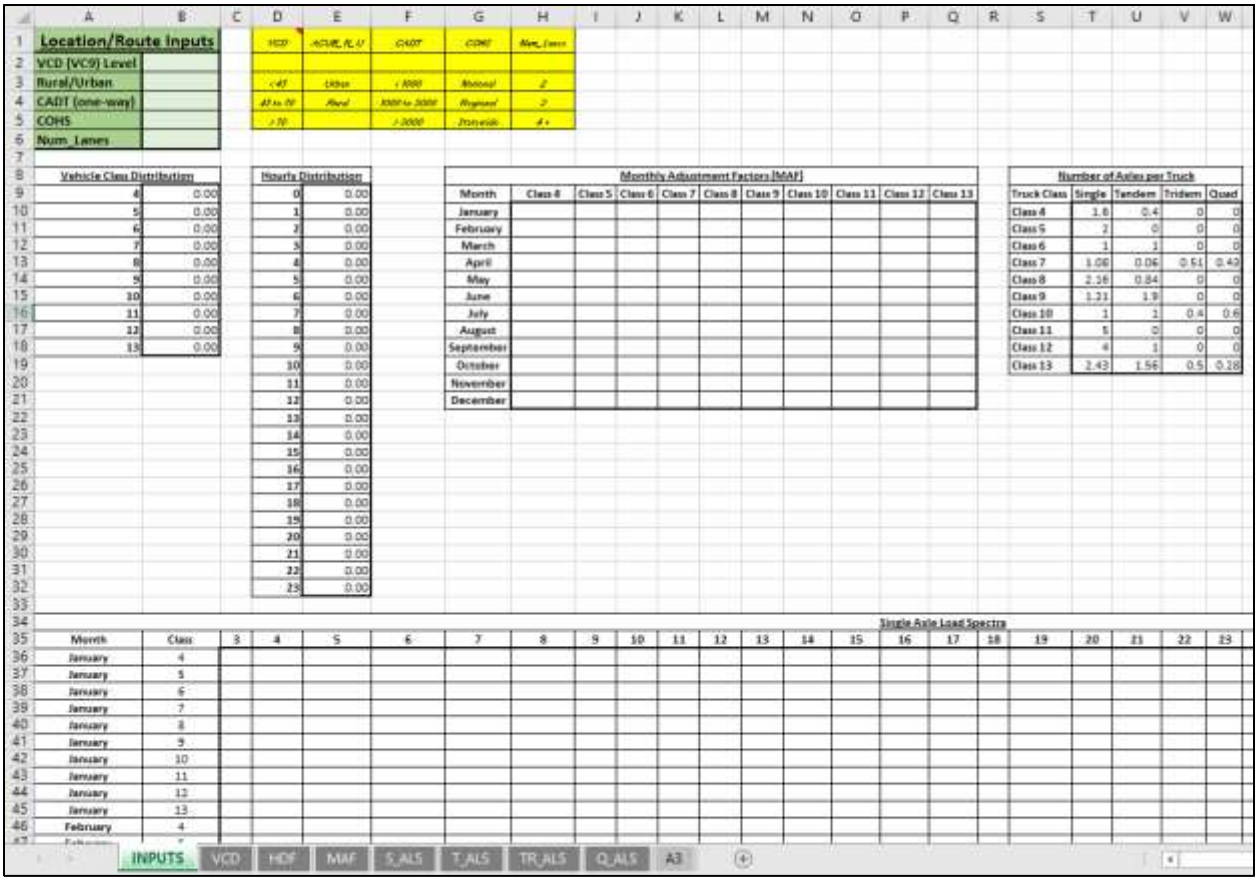
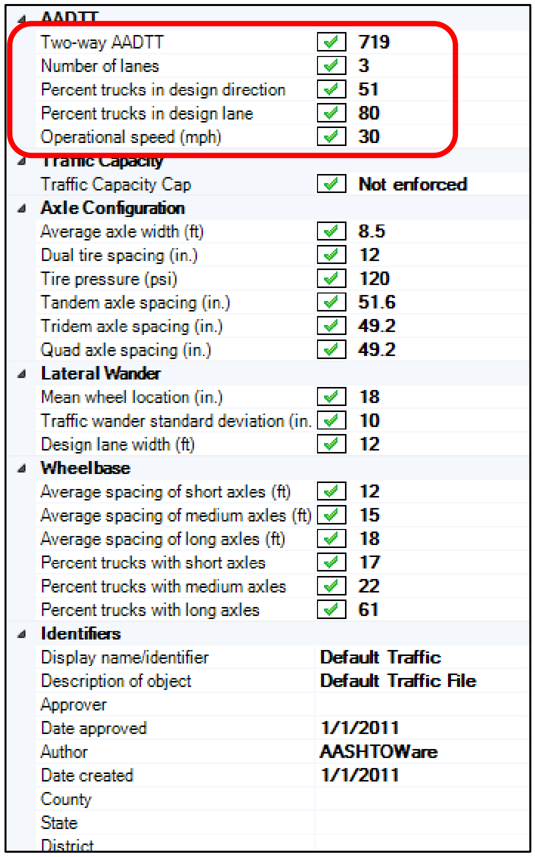



**Figure 3-4. Traffic Inputs Excel Spreadsheet**

After importing the appropriate .XML file, or copying from the Excel spreadsheet, the general traffic inputs will need to be changed. Appropriate values for Two-way AADTT, % trucks in the design direction, and % trucks in the design lane (see Figure 3-5) can be found in the traffic memo received from Statewide Transportation Planning. The designer must supply values for Number of lanes and Operational speed based on knowledge of the project site. The remainder of the inputs in Figure 3-5 should remain as the software defaults. See Chapter 7 – Traffic Inputs for more details.

*WARNING: It is important to edit these values* *after* *importing an 'XML' file. The import process overwrites these with values from the .XML file.*



| | |
|---|---|
| **AADTT** | |
| Two-way AADTT | 719 |
| Number of lanes | 3 |
| Percent trucks in design direction | 51 |
| Percent trucks in design lane | 80 |
| Operational speed (mph) | 30 |
| **Traffic Capacity** | |
| Traffic Capacity Cap | Not enforced |
| **Axle Configuration** | |
| Average axle width (ft) | 8.5 |
| Dual tire spacing (in.) | 12 |
| Tire pressure (psi) | 120 |
| Tandem axle spacing (in.) | 51.6 |
| Tridem axle spacing (in.) | 49.2 |
| Quad axle spacing (in.) | 49.2 |
| **Lateral Wander** | |
| Mean wheel location (in.) | 18 |
| Traffic wander standard deviation (in. | 10 |
| Design lane width (ft) | 12 |
| **Wheelbase** | |
| Average spacing of short axles (ft) | 12 |
| Average spacing of medium axles (ft) | 15 |
| Average spacing of long axles (ft) | 18 |
| Percent trucks with short axles | 17 |
| Percent trucks with medium axles | 22 |
| Percent trucks with long axles | 61 |
| **Identifiers** | |
| Display name/identifier | Default Traffic |
| Description of object | Default Traffic File |
| Approver | |
| Date approved | 1/1/2011 |
| Author | AASHTOWare |
| Date created | 1/1/2011 |
| County | |
| State | |
| District | |

**Figure 3-5. General Traffic Inputs**

### 3.1.7 – Step 7: Choose Climate Station

Choose the weather station closest to the project. The latitude and longitude from a point near the middle of the project can be entered to assist with determining the closest station if needed. Details on climate stations can be found in Chapter 8 – Climate Inputs. As needed, adjust the water table depth to the appropriate annual average value as outlined in Chapter 8 – Climate Inputs.

### 3.1.8 – Step 8: Add/Delete Layers; Change Material Inputs

Add and delete layers as appropriate to reflect the intended new pavement and existing pavement cross-section (for rehabilitation designs). Change inputs as necessary and allowed by Chapters 9 through 13. Common pavement layers used in Michigan have been created and can be found in the 'ME Pvmt Design\Layers' subfolder on the Construction Field Services Division common drive. These layers are in .XML format for importing into Pavement ME Design.

The asphalt mix and binder mechanical properties (mix dynamic modulus, binder shear modulus, mix indirect tensile strength, and mix creep compliance) require special consideration. The values used are dependent on the mix type (e.g. 5E30, 3E10, etc.) and binder grade selected for each layer. The binder used for a specific mix type can vary based on the region the project is to occur in. Pre-made Hot Mix Asphalt (HMA) layers for common mix types and binder by Region can be found in the 'ME Pvmt Design\Layers\HMA_common' subfolder on the Construction Field Services Division common drive. This subfolder is only available to MDOT users of Pavement ME Design. The folders contained in this subfolder and example import files are shown in Figure 3-6 below. Note that "NGBSU_Regions" pertain to North, Grand, Bay, Southwest, and University regions.

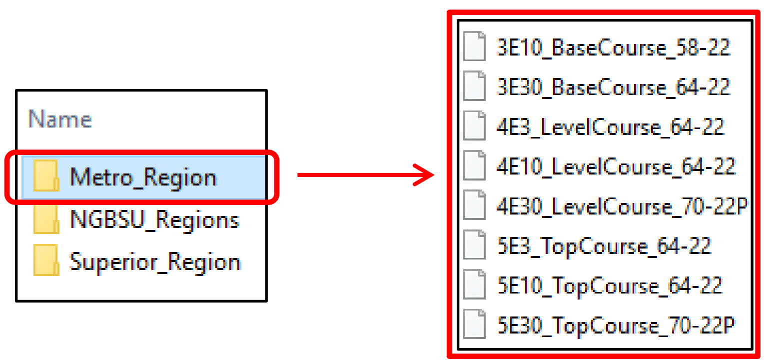



**Figure 3-6. Folder Structure for HMA_common Layers**

Pre-made HMA layers to represent all the possible combinations of Region, mix type, and binder were not created. For those mix types that are not pre-made, the designer must import the generic asphalt layers (HMA top course, HMA leveling course, HMA base course, etc.) and then import, or copy and paste, the mix and binder properties individually into each layer. Table 3-1 lists how to insert the Level 1 values for each property.

**Table 3-1. Method for Obtaining Asphalt Mix/Binder Mechanical Properties**

| Asphalt Mechanical Property | How To Obtain |
|---|---|
| Dynamic Modulus | Copy and paste from the correct mix type/binder Excel file |
| Asphalt Binder (Shear Modulus) | Import the correct binder .bif file |
| Indirect Tensile Strength | Copy and paste from the correct mix type/binder Excel file |
| Creep Compliance | Copy and paste from the correct mix type/binder Excel file |

The files necessary for these properties can be found in the 'ME Pvmt Design\HMA properties' subfolder on the Construction Field Services Division common drive. Figure 3-7 shows the subfolders under the HMA properties folder.


**Figure 3-7. Folder Structure for HMA Mechanical Properties**

The 'D(t) & IDT' folder contains the creep compliance and indirect tensile strength files, the 'E' folder contains the dynamic modulus files, and the 'G' folder contains the asphalt binder files. Under each property subfolder, the files are separated by region. Figure 3-8 shows an example of finding the dynamic modulus files for Metro Region. The asphalt binder and creep compliance/indirect tensile strength folders are similar.

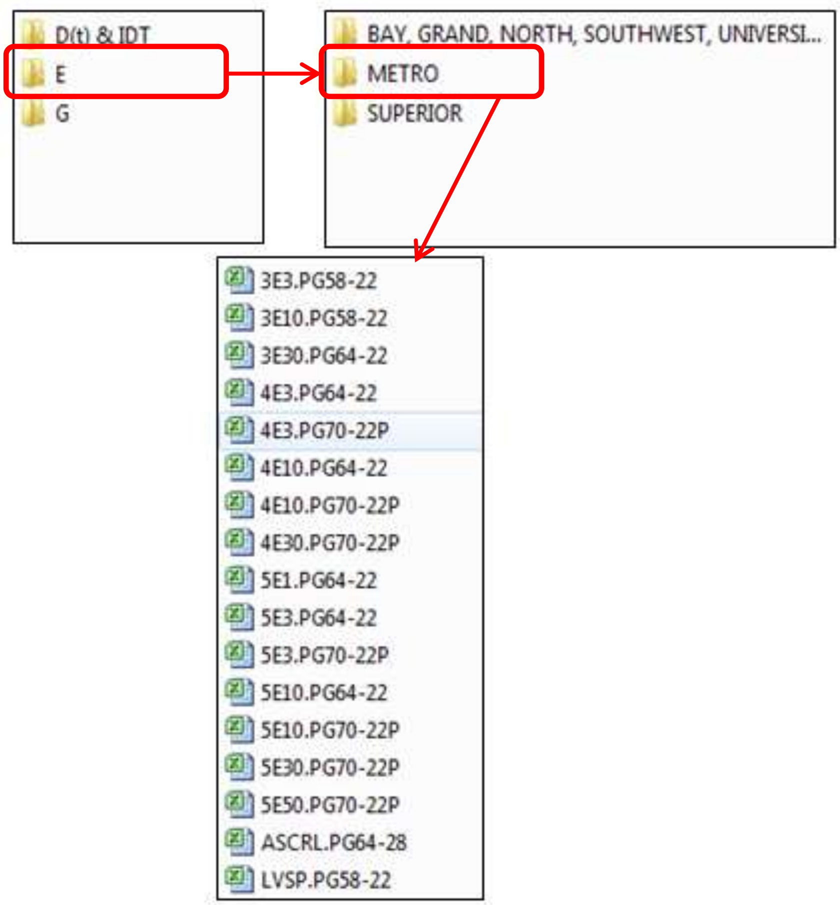



**Figure 3-8. Example of Finding the Mix Type/Binder Files for a Region**

Properties predicted using the DynaMOD software will have 'predicted' in the filename. See Section 1.3 – Michigan ME Research for a description of the DynaMOD software.

### 3.1.9 – Step 9: Review All Inputs

Because of the large number of inputs used in ME, it is recommended that a review be conducted to verify that no errors have been made. The Error List tab should be checked to make sure no errors or warnings are listed. Technically, designs can be run with warnings for specific inputs, but users should attempt to correct the reason for the warning message. Figures 3-9 and 3-10 show how error and warning messages are displayed next to the input itself, and in the Error List tab, respectively.

| Mixture Volumetrics | |
|---|---|
| Unit weight (pcf) | 95 Error: Input value is less than the allowed minimum.(100) |
| Effective binder content (%) | 11.6 |
| Air voids (%) | 1 *Warning: Value is less than the recommend minimum.(2)* |

**Figure 3-9. Error/Warning Messages Next to the Input**

Error List

| | Project | Object | Property | Description |
|---|---|---|---|---|
| | 82131_76903 HMA | Layer 1 Asphalt Concrete:HMA Top Course | Unit weight... | Error: Input value is less than the allowed minimum.(100) |
| ! | 82131_76903 HMA | Layer 1 Asphalt Concrete:HMA Top Course | Air voids (%) | Warning: Value is less than the recommend minimum.(2) |

**Figure 3-10. Error/Warning List in the Error Tab**

Contact the Pavement Management Section (see Section 1.6 – Contacts) for assistance with error/warning messages that cannot be corrected.

### 3.1.10 – Step 10: Run the Initial Trial Design

Run the analysis. If multiple designs have been created and need to be analyzed, Batch Mode can be utilized to save time (see Chapter 2 – Software Operation).

*WARNING: Close all open Excel files on your computer before running trials. Summary outputs will fail to generate if you have any open Excel files.*

### 3.1.11 – Step 11: Examine the Summary Output

Review the PDF and/or Excel output files to make sure the summaries of traffic and climate details are reasonable and that all inputs are correct.

### 3.1.12 – Step 12: Revise the Design, If Needed

Check the performance criteria predicted values and reliability levels. If they do not meet the Criteria for Design Acceptance stated in Chapter 14 – Assessing the Results/Modifying the Design, then revise the design and re-run. If the file name is not changed, the previous analysis will be overwritten. Therefore, it is recommended that the design be saved with a new file name before the new design is analyzed. This will allow for comparisons between designs if needed.

### 3.1.13 – Step 13: Submit for QA Check

When the final design has been determined, submit it to Construction Field Services Division for a quality assurance (QA) check. Designs (and all related information) completed by region pavement designers will be submitted to ProjectWise, within the job folder, under 'Pre-construction', under 'Pavement Design', in the 'Draft' folder. The Pavement Management Section at Construction Field Services Division will conduct the QA. When all documents are ready for QA, send an email according to the following Pavement Management Section personnel:

- Superior, North, Grand, and Southwest: Jami Trudelle
- Bay, University, and Metro: Justin Schenkel

The design and related information needed for QA are specified by the 'Instructions' document, found in the 'ME Pvmt Design\Submittal Forms' subfolder on the Construction Field Services Division common drive. See Section 14.5 – Final Design Verification (QA) for further information.

### 3.1.14 – Step 14: Report Final Accepted Design

After passing QA, the final design can be provided to the project manager for incorporation into the project plans.

# Chapter 4 – General Inputs

**Table 4-1. Design Type, Pavement Type, and Design Life Inputs**

| MDOT Project Types | | Recommended Values | | |
|---|---|---|---|---|
| **MDOT Design Type** | **MDOT Pavement Type** | **ME Design Type** | **ME Pavement Type** | **Design Life (years)** |
| New Reconstruct | HMA Pavement | New Pavement | Flexible Pavement | 20 |
| | Jointed Plain Concrete (JPCP) | New Pavement | Jointed Plain Concrete Pavement (JPCP) | 20 |
| Rehab | Unbonded Concrete (≥6”) over JPCP/JRCP | Overlay | JPCP over JPCP (unbonded) | 20 |
| | Unbonded Concrete (≥6”) over Composite | Overlay | JPCP over (conc. type*) (unbonded) | 20 |
| | Unbonded Concrete (≥6”) over CRCP | Overlay | JPCP over CRCP (unbonded) | 20 |
| | Multi-course HMA over Rubblized JPCP/JRCP/CRCP | New Pavement | Flexible Pavement | 20 |
| | Multi-course HMA over Crush & Shape HMA | New Pavement | Flexible Pavement | 15 |
| | Multi-course HMA (with/without ASCRL) over HMA | Overlay | AC over AC | 15 or 20 |
| | Multi-course HMA(with/without ASCRL) over JPCP/JRCP | Overlay | AC over JPCP | 15 or 20 |
| | Multi-course HMA(with/without ASCRL) over CRCP | Overlay | AC over CRCP | 15 or 20 |
| | Multi-course HMA(with/without ASCRL) over Composite | Overlay | AC over (conc. type**) | 15 or 20 |
| | Aggregate-lift and JPCP | New Pavement | Jointed Plain Concrete Pavement (JPCP) | 20 |
| | Aggregate-lift and Multi-course HMA | New Pavement | Flexible Pavement | 20 |

* = choose JPCP over JPCP (unbonded) when underlying concrete is JPCP/JRCP;
choose JPCP over CRCP (unbonded) when underlying concrete is CRCP

** = choose AC over JPCP when underlying concrete is JPCP/JRCP;
choose AC over CRCP when underlying concrete is CRCP

**Table 4-2. Construction/Open to Traffic Inputs**

| Input | Recommended Values | |
|---|---|---|
| | **Month** | **Year** |
| Existing Construction | Month of last pavement placed (use August if Month is unknown) | Year of last pavement placed |
| Base Construction | July | Expected year of construction |
| Pavement Construction | August | Expected year of construction |
| Traffic Opening | September | Expected year of construction |

| | |
|---|---|
| Special Traffic Loading for Flexible Pavements | Do not select (only use for research or informational purposes) |

### 4.1 – Introduction

The general information area of Pavement ME Design contains the design type, pavement type, and design life inputs. Also included are inputs for the month/year of construction of various layers (depending on the design type/pavement type combination chosen) and a check box for including special traffic loading for an asphalt design. Figure 4-1 shows an example of the inputs needed for an asphalt new/reconstruct design.

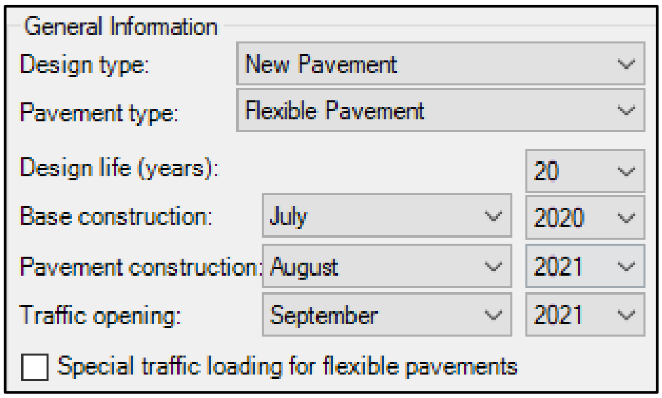



**Figure 4-1. General Information Input Area**

### 4.2 – General Information Inputs

Design Type

The choices for this input are New Pavement, Overlay, and Restoration. Select 'New Pavement' when designing a new/reconstruct project, an asphalt crush and shape project, or an aggregate lift with asphalt resurfacing project. Select 'Overlay' when designing a project that overlays an existing paved surface that will remain intact or for a concrete rubblization project. Restoration is for concrete repair and/or diamond grinding projects. Even though MDOT does use concrete repair and diamond grinding of its concrete pavements, the Restoration design will not be used because the models have not been validated or calibrated in Michigan.

Pavement Type

The selectable choices for Pavement Type will depend on what is selected for Design Type:

- New Pavement
    - Flexible Pavement
    - Jointed Plain Concrete Pavement
    - Continuously Reinforced Concrete Pavement
    - Semi-Rigid Pavement

- Overlay (asphalt is referred to as AC in the software)
    - AC over AC
    - AC over AC with Seal Coat
    - AC over AC with Interlayer
    - AC over Semi-Rigid
    - AC over JPCP
    - AC over CRCP
    - AC over JPCP (fractured)
    - Bonded PCC/JPCP
    - Bonded PCC/CRCP
    - JPCP over CRCP (unbonded)
    - JPCP over JPCP (unbonded)
    - CRCP over CRCP (unbonded)
    - CRCP over JPCP (unbonded)
    - JPCP over AC
    - CRCP over AC
    - SJPCP over AC
- Restoration
    - JPCP Restoration

Not all the above options will be used for MDOT pavement designs. See Section 1.4 – Design Types and Table 4-1 for project types that will be designed with ME in Michigan.

Design Life

The value entered for Design Life will depend on the project type. See Table 4-1 for the values to enter.

Existing Construction

Enter month and year of construction of the existing paved surface. If the month is not known, use August. For situations where different layers of the existing paved surface were paved in different years (composite pavements, multiple asphalt overlays, mill and resurfacing projects, etc.), enter the year of the last paving project.

Base Construction

This input only appears for a new/reconstruct flexible design. Select 'July' and enter the anticipated year of construction. Since the exact month is not typically known when the pavement design is created and it has almost no impact on the results, July was determined to be a reasonable month for when a base layer would be constructed.

Pavement Construction

Select 'August' and enter the anticipated year of construction. Since the exact month is not typically known when the pavement design is created and it has almost no impact on the results, August was determined to be a reasonable month for when the pavement surface layer would be constructed.

Traffic Opening

Select 'September' and enter the anticipated year of construction. Since the exact month is not typically known when the pavement design is created and it has almost no impact on the results, September was determined to be a reasonable month for when the project will be opened to traffic.

Special Traffic Loading

This option allows an analysis of the pavement response to a special axle weight or configuration. It is only available in flexible designs (new/reconstruct asphalt, rubblize, and asphalt over asphalt). Selecting this option (by checking the box) removes all the standard traffic inputs and replaces them with the following:

- Tire load: the load experienced by a single tire in pounds (lbs). All other tires are assumed to carry the same load.
- Tire pressure: the hot inflation pressure of the tires in pounds per square inch (psi).
- Standard Deviation of Wheel Wander: this is the standard deviation of wheel location away from the mean wheel location in inches.
- Begin date: the starting date of special loading.
- End data: the end date of special loading.
- Monthly repetitions: the number of repetitions per month of the special loading configuration.
- Annual growth: the percent growth rate of the monthly repetitions (software assumes linear growth – there is not option for compound growth).
- Tire location:
    - Number of tires: the number of tires and the location of those tires in an x/y coordinate system (entered in inches).
    - Number of analysis locations in transverse direction: locations in the traffic direction to calculate the stresses/strains from the special loading. This is entered in inches.

The normal traffic inputs are removed for this analysis, i.e. the entire traffic stream will consist of the special axle configuration. Therefore, it should only be used for research or informational purposes.

## 4.3 – Project Identifiers

The project identifiers area appears in the Property Grid area of the Project Tab Pane as shown in Figure 4-2 below.

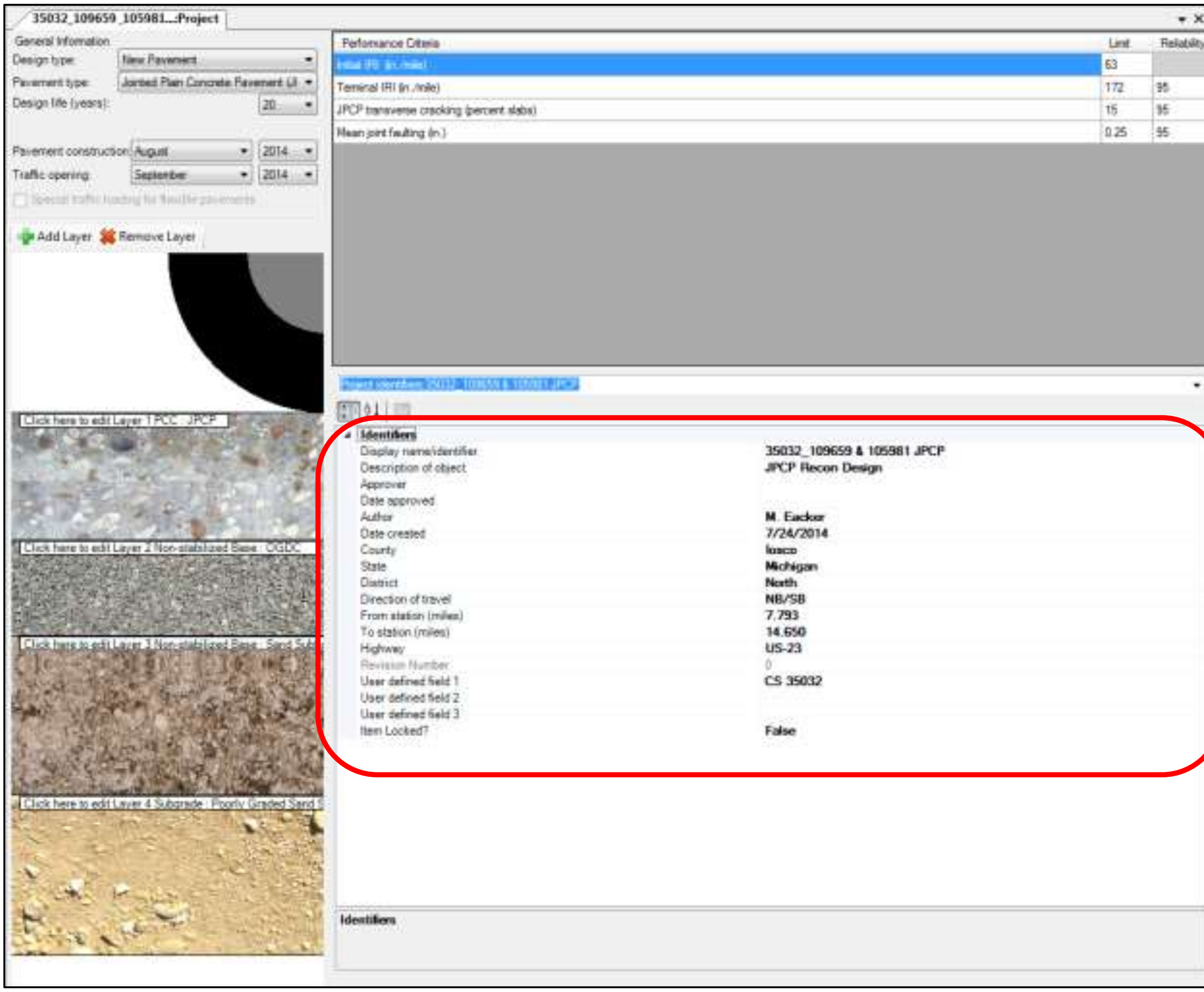



**Figure 4-2. Location of Project Identifiers**

This area is accessed by selecting 'Project Identifiers' from the Project Tab drop-down menu. The 'Display name/identifier' field will be populated automatically with the filename. The designer should fill in the remainder of the fields as appropriate. This is useful for future reference and for the QA reviewer. The three 'User defined field' items can be used for adding additional information not captured in the other items. If projects are stored in the ME database (see Chapter 2), these fields are searchable for quickly locating specific projects. The control section(s) for the project are recommended to be placed in 'User defined field 1'. Lastly, the 'Item Locked?' field is automatically filled in as "False" which indicates that the project can be edited. A value of "True" locks all fields/inputs and makes the project read-only.

# Chapter 5 – Performance Criteria and Reliability

**Table 5-1. Asphalt Distress Thresholds and Reliability**

| Criteria | Units | Recommended Value | Recommended Reliability |
|---|---|---|---|
| Initial IRI | inches/mile | 67 | 95% |
| Terminal IRI | inches/mile | 172 | 95% |
| Top-down fatigue cracking | feet/mile | Do not use (2000) | Do not use (95%) |
| Bottom-up fatigue cracking | % surface area | 20 | 95% |
| Transverse thermal cracking | feet/mile | 1000 | 95% |
| Total rutting | inches | 0.5 | 95% |
| Asphalt rutting | inches | Do not use (0.5) | Do not use (95%) |
| Chemically stabilized layer – fatigue fracture (overlays only) | % lane area | Do not use* | Do not use* |
| Total fatigue cracking – bottom-up plus reflective (overlays only) | % surface area | Do not use* | Do not use* |
| Total transverse cracking – thermal plus reflective (overlays only) | feet/mile | Do not use* | Do not use* |
| JPCP cracking (overlays only) | % slabs cracked | Do not use* | Do not use* |
| CRCP punchouts (overlays only) | number/mile | Do not use* | Do not use* |

* = A value must still be entered, leave the software default in place. Values in parentheses are recommended to be entered despite the criteria not being used.

**Table 5-2. Concrete Distress Thresholds and Reliability**

| Criteria | Units | Recommended Value | Recommended Reliability |
|---|---|---|---|
| Initial IRI | inches/mile | 72 | 95% |
| Terminal IRI | inches/mile | 172 | 95% |
| Transverse cracking | % slabs cracked | 15 | 95% |
| Mean joint faulting | Inches | 0.125 | 95% |

***NOTE**: IRI is International Roughness Index (a measure of pavement smoothness, or ride quality)*

## 5.1 – Introduction

Figures 5-1 and 5-2 show examples of the performance criteria and reliability inputs for a new/reconstruct asphalt and new/reconstruct concrete design respectively. Inputs for rehabilitation designs look similar, with only asphalt overlays having a few additional criteria as noted in Table 5-1.

| Performance Criteria | Limit | Reliability |
|---|---|---|
| Initial IRI (in/mile) | 67 | |
| Terminal IRI (in/mile) | 172 | 95 |
| AC top-down fatigue cracking (ft/mile) | 2000 | 95 |
| AC bottom-up fatigue cracking (% lane area) | 20 | 95 |
| AC thermal cracking (ft/mile) | 1000 | 95 |
| Permanent deformation - total pavement (in) | 0.5 | 95 |
| Permanent deformation - AC only (in) | 0.5 | 95 |

**Figure 5-1. Asphalt New/Reconstruct Performance Criteria/Reliability Area**

| Performance Criteria | Limit | Reliability |
|---|---|---|
| Initial IRI (in/mile) | 63 | |
| Terminal IRI (in/mile) | 172 | 95 |
| JPCP transverse cracking (percent slabs) | 15 | 95 |
| Mean joint faulting (in) | 0.125 | 95 |

**Figure 5-2. Concrete New/Reconstruct Performance Criteria/Reliability Area**

Each of the performance criteria are pavement distresses (except in the case of IRI), and thus the two terms typically are used interchangeably. The limit value is the maximum amount of that distress (or IRI) that is acceptable at the end of the design life. It is also referred to as the distress threshold. The reliability value is the desired minimum probability that the distress threshold is not exceeded during the design life. The limit, reliability, and design life values entered are interconnected for determining if the design passes for each of the performance criteria. In order for a performance criteria to be given a result of "Pass", the predicted amount must be below the limit value at the end of the design life, at a reliability above the target reliability value.

If a starter design file is utilized as mentioned in Chapter 3, the performance criteria and reliabilities will already be set to the recommended MDOT design values. It is recommended that the designer verify that the values are correct for the intended design. If a starter design file is not used, these inputs will need to be entered using the values from Tables 5-1 or 5-2 above.

## 5.2 – Performance Criteria

Generally, the list of the performance criteria available depends on the type of pavement that is on the surface: asphalt, JPCP, or CRCP. Table 5-3 provides the criteria that are available for each:

**Table 5-3. List of Available Performance Criteria**

| | Criteria | Units |
|---|---|---|
| ASPHALT | Terminal IRI | inches/mile |
| | Top-down fatigue cracking | feet/mile |
| | Bottom-up fatigue cracking | % surface area |
| | Transverse thermal cracking | feet/mile |
| | Total rutting | inches |
| | Asphalt rutting | inches |
| | Chemically stabilized layer – fatigue fracture (overlays only) | % lane area |
| | Total fatigue cracking – bottom-up plus reflective (overlays only) | % surface area |
| | Total transverse cracking – thermal plus reflective (overlays only) | feet/mile |
| | JPCP cracking (overlays only) | % slabs cracked |
| | CRCP punchouts (overlays only) | number/mile |
| JPCP | Terminal IRI | inches/mile |
| | Transverse cracking | inches/mile |
| | Mean joint faulting | % slabs cracked |
| CRCP | Terminal IRI | inches/mile |
| | Punchouts | number/mile |

The performance criteria units shown in Table 5-3 are on a per lane or lane/mile basis. They may not represent amounts for the entire length of the proposed project, so the designer should keep that in mind when viewing the results for those criteria.

### 5.2.1 – Smoothness

The performance criteria that is common to all designs in ME is pavement smoothness. Smoothness is measured using the International Roughness Index, or IRI. IRI has units of inches/mile. There are two IRI values that must be entered for every ME design: initial IRI and terminal IRI.

Initial IRI

The initial IRI is the expected smoothness of the pavement at the time it is opened to traffic. After project construction, there are no distresses, so ME begins with the performance criteria at 0. The exception to this is the IRI. At opening to traffic, IRI is a non-zero value because pavements are not constructed perfectly smooth. To accommodate this fact, ME requires an additional input in the performance criteria area to indicate the initial IRI. ME uses the initial IRI value as the starting point and IRI will increase with time according to the IRI model. Initial IRI does not have an associated reliability because it only represents a starting point. The terminal IRI (see below), however, does have a reliability value.

For Michigan pavements, the following values will be used:

- New asphalt projects (includes crush and shape, and aggregate lift projects) = 67
- New concrete projects = 72

Terminal IRI

The IRI models in ME are empirically derived based on the amount of distresses predicted and a site factor. If damage is being accumulated in the design, predicted distresses will increase. As the distresses increase, the predicted IRI will increase as well. The site factors are properties of the project site that will also affect the IRI. The properties affecting the site factor are *(3)*:

- Asphalt pavements
    - Age of the pavement, years
    - Plasticity Index of the subgrade
    - Freezing index, ˚F days
    - Average annual precipitation, inches
- Jointed plain concrete pavements
    - Age of the pavement, years
    - Freezing index, ˚F days
    - Subgrade percent passing the #200 sieve
    - % of joints with spalls, predicted based on the following:
        - Age of the pavement, years
        - Concrete air content, %
        - Type of joint sealant (preformed or other)
        - Concrete compressive strength, psi
        - Average number of annual freeze-thaw cycles
        - Concrete thickness, inches
        - Concrete water to cement ratio
- Continuously reinforced concrete pavements
    - Age of the pavement, years
    - Freezing index, ˚F days
    - Subgrade percent passing the #200 sieve

The software default of 172 inches/mile was adopted as the terminal IRI.

### 5.2.2 – Asphalt Performance Criteria

Bottom-Up Fatigue Cracking

Bottom-up fatigue cracking is load related cracking in the wheel path that initiates at the bottom of the asphalt layers. With continued loading, they ultimately progress to what is commonly referred to as alligator cracking. This name derives from the fact that the surface appearance is that of a series of parallel longitudinal cracks interconnected by short transverse cracks. This pattern looks very much like the hide of an alligator. Bottom-up fatigue cracking is measured by the percentage of the overall lane surface that is alligator cracked.

A value of 20% was adopted as the threshold.

Top-Down Fatigue Cracking

Top-down fatigue cracking is similar to bottom-up fatigue cracking in that they are both types of longitudinal cracking. It initiates at the surface of the asphalt layers and differs from bottom-up in the units used to describe it: lineal feet of cracking versus percent surface area cracked for bottom-up.

During the local calibration process, the measured top-down cracking data from in-service pavements was included in the bottom-up cracking model. It was determined that this provided a better cracking calibration. For this reason, MDOT will not be utilizing top-down cracking performance criteria for judging the acceptability of a design. However, values in Table 5.1 are still recommended to be entered.

Thermal Cracking

Thermal cracking is transverse cracking that occurs due to temperature cycling. Low temperatures are typically what cause thermal cracking. Thermal cracking is measured in lineal feet of cracking per lane mile.

The software default of 1000 feet/mile was adopted as the threshold. This equates to an average crack spacing of 63 feet for a 12-foot-wide lane.

Total Rutting

Rutting is the vertical deformation found in the wheel paths. ME calculates the vertical strain at the top of the asphalt, unbound granular, and subgrade layers to determine the amount of rutting for each. The amount of rutting for each layer is summed to obtain the total rutting prediction. It represents the average rut depth for both wheel paths. Rutting is measured in inches.

A value of 0.5 inches was adopted as the threshold.

Asphalt Rutting

Asphalt rutting is the portion of total rutting contributed by the asphalt layer(s) only. Previous versions of the software assumed asphalt rutting to be equivalently contributed by all asphalt layers in the cross-section. The contribution from individual asphalt layers to the overall asphalt rutting can be varied/customized. However, this requires measurement data on the rutting in each asphalt layer from in-service pavements. Since MDOT does not have this data, the former assumption of equal contribution among the asphalt layers will be continued. Asphalt rutting is measured in inches.

During the calibration process, the only rutting data available was for total rutting. Therefore, total rutting was calibrated while rutting in the asphalt, granular, and subgrade layers was not. For this reason, MDOT will not be utilizing the asphalt rutting performance criteria for judging the acceptability of a design.

Chemically stabilized layer – fatigue fracture (Asphalt Overlays)

The chemically stabilized layer – fatigue fracture performance criteria only appears for asphalt overlays of existing asphalt pavements with semi-rigid/cement stabilized bases (directly under the existing asphalt layer). This is measured by the percentage of the overall lane that is cracked in the underlying chemically stabilized base layer(s). The amount of cracking increases as load related damage accumulates in the semi-rigid base.

Since this type of pavement is not standard for MDOT, this performance criteria will not be used.

Total Fatigue Cracking (Asphalt Overlays)

The total fatigue cracking performance criteria only appears for asphalt overlays of intact pavement. The total fatigue cracking is a summation of bottom-up fatigue cracking and reflection cracking. Total cracking is measured by the percentage of the overall lane surface that exhibits bottom-up and reflective cracking.

Data to determine the amount of reflective cracking (versus fatigue cracking) occurring in the overlay surface asphalt was not available, so this performance criteria was not calibrated. For these reasons, MDOT will not be using it for judging the acceptability of a design.

Total Transverse Cracking (Asphalt Overlays)

The total transverse cracking performance criteria only appears for asphalt overlays of intact pavement. The total transverse cracking is a summation of thermal cracking and reflection cracking. This is measured in lineal feet of cracking per lane mile.

Data to determine the amount of reflective cracking (versus thermal cracking) occurring in the overlay surface asphalt was not available, so this performance criteria was not calibrated. For these reasons, MDOT will not be using it for judging the acceptability of a design.

JPCP Cracking (Asphalt Overlays)
When a jointed plain concrete pavement is overlaid with asphalt, ME assumes that damage to the underlying concrete (in the form of transverse cracking) continues. JPCP cracking is measured by the percentage of slabs that are cracked.

Data for the amount of cracking occurring after the overlay was placed was not available, so this performance criteria was not calibrated. For these reasons, MDOT will not be using it for judging the acceptability of a design.

CRCP Punchouts (Asphalt Overlays)
When a continuously reinforced pavement is overlaid with asphalt, ME assumes that damage to the underlying concrete (in the form of punchouts) continues. CRCP punchouts are measured by the number per mile.

Asphalt overlay of CRCP projects were unavailable for use in calibration. Therefore, this performance criteria was not calibrated. For these reasons, MDOT will not be using it for judging the acceptability of a design.

### 5.2.3 – JPCP Performance Criteria

Transverse Cracking
ME has models that predict the amount of top-down and bottom-up transverse cracking in the concrete slab. These two predictions are combined into one value to arrive at a transverse cracking total. Transverse cracking is measured by the percentage of slabs that are cracked.

The software default of 15% was adopted as the threshold.

Mean Joint Faulting
Faulting is the vertical difference between the slabs on either side of a transverse joint in JPCP. The predicted value represents the expected average per joint for the design. Faulting is measured in inches.

A value of 0.125 inches was adopted as the threshold.

### 5.2.4 – CRCP Performance Criteria

Punchouts
Punchouts are the primary structural distress for continuously reinforced concrete pavements. CRCP pavements are expected to crack transversely since no transverse joints are used to control cracking. A punchout occurs when longitudinal cracks connect two transverse cracks and the resulting piece of concrete settles or “punches down”. Punchouts are measured by the number that occur per mile.

Since CRCP pavements are not standard for MDOT, this performance criteria will not be used.

## 5.3 – Reliability

Reliability is defined as the probability that the predicted distress is less than the threshold value over the entire design life *(3)*. For example, setting the reliability to 95% for terminal IRI means that the designer wants a 95% probability (95 or more out of every 100 projects) that the predicted IRI does not exceed the terminal IRI limit value during the design period. ME differs from the AASHTO 1993 design method in that multiple reliabilities are considered (one for each performance criteria) instead of just one.

The performance criteria are assumed to be normally distributed as shown in Figure 5-3 *(3)*. ME will predict the mean (or 50% probability value) and then multiply the standard error by a factor representing the reliability level desired, to obtain the estimate of the performance criteria, at that reliability level. For example, the factor for 95% reliability is 1.96 standard errors. For 95% reliability, ME will multiply the standard error for that performance criteria by 1.96, and add this to the mean predicted value to obtain the predicted distress at a 95% probability. The portion of the standard distribution curve above the threshold level is considered the probability of failure.

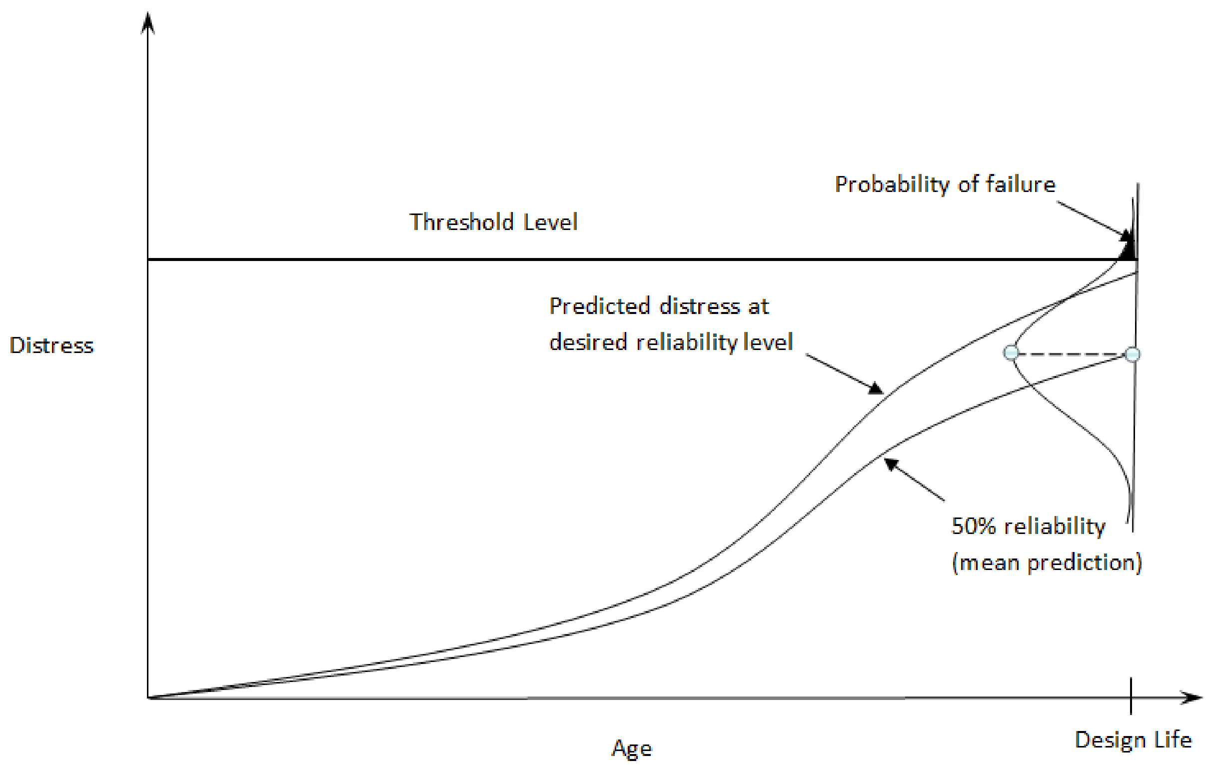



**Figure 5-3. Prediction at Specified Reliability Level Versus Mean Prediction**

In Figure 5-3, the design would pass, for this particular performance criteria, since the predicted distress at the desired reliability does not exceed the threshold level.

Even though the reliability can be set at different levels for each of the performance criteria, it has been recommended that the same level be used for all *(3)*. A value of 95% was adopted for all MDOT designs.

# Chapter 6 – Calibration Coefficients

RED/UNDERLINE = values that change from the software default

**Table 6-1. Calibration Coefficients for New Flexible**

| Category | Coefficient/Std. Dev. | Value |
|---|---|---|
| AC Cracking | Bottom Standard Deviation | 0.7874+17.817/(1+exp(0.0699-0.4559*LOG 10(Bottom))) |
| | C1 bottom | 0.5 |
| | C1 top | 3.32 |
| | C2 bottom | 0.56 |
| | C2 top | 1.25 |
| | C3 bottom | 6000 |
| | C3 top | 0 |
| | C4 top | 1000 |
| | Top Standard Deviation | 150+2300/(1+exp(1.9-0.6*LOG 10(Top + 0.0001))) |
| AC Fatigue | BF1 | 1 |
| | BF2 | 1 |
| | BF3 | 1 |
| | K1 | 0.007566 |
| | K2 | 3.9492 |
| | K3 | 1.281 |
| AC Rutting | Standard Deviation | 0.1126*Pow(RUT,0.2352) |
| AC Rutting (Layers 1, 2, and 3) | BR1 | 0.9453 |
| | BR2 | 1.3 |
| | BR3 | 0.7 |
| | K1 | -3.35412 |
| | K2 | 1.5606 |
| | K3 | 0.4791 |
| CSM Cracking | C1 | 0 |
| | C2 | 75 |
| | C3 | 5 |
| | C4 | 3 |
| | Standard Deviation | CTB*1 |
| CSM Fatigue | BC1 | 0.75 |
| | BC2 | 1.1 |
| | K1 | 1 |
| | K2 | 1 |
| IRI | C1 | 50.372 |
| | C2 | 0.4102 |
| | C3 | 0.0066 |
| | C4 | 0.0068 |
| | Over PCC1 | 40.8 |
| | Over PCC2 | 0.575 |
| | Over PCC3 | 0.0014 |
| | Over PCC4 | 0.00825 |

| Category | Coefficient/Std. Dev. | Value |
|---|---|---|
| **Reflective Fatigue Cracking Semi-Rigid** | C1 | 1.64 |
| | C2 | 1.1 |
| | C3 | 0.19 |
| | C4 | 62.1 |
| | C5 | -404.6 |
| | K1 | 0.45 |
| | K2 | 0.05 |
| | K3 | 1 |
| | Standard Deviation | 1.3897 * Pow(FATIGUE,0.2960) + 0.4212 |
| **Reflective Transverse Cracking Semi-Rigid** | M-value | 120 |
| | C1 | 0.1 |
| | C2 | 0.9809 |
| | C3 | 0.19 |
| | C4 | 165.3 |
| | C5 | -5.1048 |
| | K1 | 0.45 |
| | K2 | 0.05 |
| | K3 | 1 |
| | Standard Deviation | 0.000027 * Pow(TRANSVERSE,2.1187) + 399.9 |
| **Subgrade Rutting** | Fine BS1 | 0.0367 |
| | Fine K1 | 1.35 |
| | Fine Stand. Dev. | 3.6118 * Pow(SUBRUT,1.0951) |
| | Granular BS1 | 0.0985 |
| | Granular K1 | 2.03 |
| | Granular Stand. Dev. | 0.1145 * Pow(BASERUT,0.3907) |
| **Thermal Fracture** | Level 1 Stand. dev. | 0.4258 * THERMAL + 210.08 |
| | Level 1K | Per HMA Top Course Binder PG Low Grade:<br>• PG ##-34: 0.625<br>• All others: 0.75 |
| | Level 2 Stand. Dev. | 0.2841 * THERMAL + 55.462 |
| | Level 2K | 0.5 |
| | Level 3 Stand. Dev. | 0.7737 * THERMAL + 622.92 |
| | Level 3K | 4 |

**Table 6-2. Calibration Coefficients for Rehabilitation Flexible**

| Category | Coefficient/Std. Dev. | Value |
|---|---|---|
| AC Cracking | Bottom Stand. Dev. | 1.13 + 13/(1+exp(7.57-15.5*LOG10(BOTTOM+0.0001))) |
| | C1 bottom | 1 |
| | C1 top | 2.97 |
| | C2 bottom | 1 |
| | C2 top | 1.2 |
| | C3 bottom | 6000 |
| | C3 top | 0 |
| | C4 top | 1000 |
| | Top Stand. Dev. | 300 + 3000/(1+exp(1.8-0.61*LOG10(TOP+0.0001))) |
| AC Fatigue | BF1 | 1 |
| | BF2 | 1 |
| | BF3 | 1 |
| | K1 | 0.007566 |
| | K2 | 3.9492 |
| | K3 | 1.281 |
| AC Rutting | Standard Deviation | 0.1126 * Pow(RUT,0.2352) |
| AC Rutting (Layers 1, 2, 3, and 4) | BR1 | 0.9453 |
| | BR2 | 1.3 |
| | BR3 | 0.7 |
| | K1 | -3.35412 |
| | K2 | 1.5606 |
| | K3 | 0.4791 |
| CSM Cracking | C1 | 0 |
| | C2 | 75 |
| | C3 | 5 |
| | C4 | 3 |
| | Standard Deviation | CTB*11 |
| CSM Fatigue | BC1 | 0.75 |
| | BC2 | 1.1 |
| | K1 | 1 |
| | K2 | 1 |
| IRI | C1 | 21.4303 |
| | C2 | 0.16 |
| | C3 | 0.0049 |
| | C4 | 0.0271 |
| | Over PCC1 | 40.8 |
| | Over PCC2 | 0.575 |
| | Over PCC3 | 0.0014 |
| | Over PCC4 | 0.00825 |

| Category | Coefficient/Std. Dev. | Value |
|---|---|---|
| **Reflective Fatigue Cracking AC and/or Semi-Rigid** | C1 | 0.38 |
| | C2 | 1.66 |
| | C3 | 2.72 |
| | C4 | 105.4 |
| | C5 | -7.02 |
| | K1 | 0.012 |
| | K2 | 0.005 |
| | K3 | 1 |
| | Standard Deviation | 1.1097 * Pow(FATIGUE,0.6804) + 1.23 |
| **Reflective Transverse Cracking AC and/or Semi-Rigid** | C1 | 3.22 |
| | C2 | 25.7 |
| | C3 | 0.1 |
| | C4 | 133.4 |
| | C5 | -72.4 |
| | K1 | 0.012 |
| | K2 | 0.005 |
| | K3 | 1 |
| | Standard Deviation | 70.98 * Pow(TRANSVERSE,0.2994) + 30.12 |
| **Reflective Transverse Cracking CRCP/Fractured** | C1 | 1.0375 |
| | C2 | 1.8929 |
| | C3 | 0.1 |
| | C4 | 262.1 |
| | C5 | -9.6645 |
| | K1 | 0.012 |
| | K2 | 0.0002 |
| | K3 | 0.1 |
| | Standard Deviation | 52.54 * Pow(TRANSVERSE,0.39) + 283.3 |
| **Reflective Transverse Cracking JPCP** | C1 | 0.1 |
| | C2 | 0.52 |
| | C3 | 3.1 |
| | C4 | 79.5 |
| | C5 | -2.71 |
| | K1 | 0.012 |
| | K2 | 0.005 |
| | K3 | 1 |
| | Standard Deviation | 5.1025 * Pow(TRANSVERSE,0.6513) + 30.12 |
| **Subgrade Rutting** | Fine BS1 | 0.0367 |
| | Fine K1 | 1.35 |
| | Fine Stand. Dev. | 3.6118 * Pow(SUBRUT,1.0951) |
| | Granular BS1 | 0.0985 |
| | Granular K1 | 2.03 |
| | Granular Stand. Dev. | 0.1145 * Pow(BASERUT,0.3907) |
| **Thermal Fracture** | Level 1 K | Per HMA Top Course Binder PG Low Grade:<br>• PG ##-34: 0.625<br>• All others: 0.75 |
| | Level 2 K | 0.5 |
| | Level 3 K | 4 |

**Table 6-3. Calibration Coefficients for New Rigid**

| Category | Coefficient/Std. Dev. | Value |
|---|---|---|
| **PCC Cracking** | C1 | 2 |
| | C2 | 1.22 |
| | C4 | 0.52 |
| | C5 | -2.17 |
| | Standard Deviation | 3.5522 * Pow(CRACK,0.3415) + 0.75 |
| **PCC Faulting** | C1 | 0.595 |
| | C2 | 1.636 |
| | C3 | 0.00217 |
| | C4 | 0.00444 |
| | C5 | 250 |
| | C6 | 0.47 |
| | C7 | 7.3 |
| | C8 | 400 |
| | Standard Deviation | 0.07162 * Pow(FAULT,0.368) + 0.00806 |
| **PCC IRI-CRCP** | C1 | 3.15 |
| | C2 | 28.35 |
| | Standard Deviation | 5.4 |
| **PCC IRI-JPCP** | J1 | 0.8203 |
| | J2 | 0.4417 |
| | J3 | 1.4929 |
| | J4 | 25.24 |
| | Standard Deviation | 5.4 |
| **PCC Longitudinal Cracking** | C4 | 0.4 |
| | C5 | -2.21 |
| | Standard Deviation | 3.5522 * Pow(LCRACK,0.4315) + 0.5 |
| **PCC Punchout** | C1 | 2 |
| | C2 | 1.22 |
| | C3 | 107.73 |
| | C4 | 2.475 |
| | C5 | -0.785 |
| | Crack | 1 |
| | Standard Deviation | 2.208 * Pow(PO,0.5316) |

**Table 6-4. Calibration Coefficients for Unbonded Rigid**

| Category | Coefficient/Std. Dev. | Value |
|---|---|---|
| **PCC Cracking** | C1 | 2 |
| | C2 | 1.22 |
| | C4 | 0.52 |
| | C5 | -2.17 |
| | Standard Deviation | 3.5522 * Pow(CRACK,0.3415) + 0.75 |
| **PCC Faulting** | C1 | 0.595 |
| | C2 | 1.636 |
| | C3 | 0.00217 |
| | C4 | 0.00444 |
| | C5 | 250 |
| | C6 | 0.47 |
| | C7 | 7.3 |
| | C8 | 400 |
| | Standard Deviation | 0.07162 * Pow(FAULT,0.368) + 0.00806 |
| **PCC IRI-CRCP** | C1 | 3.15 |
| | C2 | 28.35 |
| | Standard Deviation | 5.4 |
| **PCC IRI-JPCP** | J1 | 0.8203 |
| | J2 | 0.4417 |
| | J3 | 1.4929 |
| | J4 | 25.24 |
| | Standard Deviation | 5.4 |
| **PCC Punchout** | C1 | 2 |
| | C2 | 1.22 |
| | C3 | 107.73 |
| | C4 | 2.475 |
| | C5 | -0.785 |
| | Crack | 1 |
| | Standard Deviation | 2.208 * Pow(PO,0.5316) |

## 6.1 – Introduction

The prediction models in ME have been calibrated using Long-Term Pavement Performance (LTPP) test sections from around the United States and Canada. This calibration is commonly referred to as the global calibration and resulted in the global calibration coefficients. These global coefficients are also used as the default values in the ME software. While the use of these coefficients can result in appropriate designs, it has been strongly recommended that each transportation agency that uses the ME design method, calibrate to their local conditions. That way there is a stronger correlation between ME predictions and actual performance experienced by each agency.

Per this recommendation, MDOT sponsored two research projects, (both conducted by Michigan State University) to calibrate the ME software to Michigan conditions. This research utilized observed performance measurements from the MDOT Pavement Management System (PMS) to calibrate the predictions of the ME software. The measured distress levels of many in-service pavements were compared to the predicted distresses from ME. The primary objective of calibration is to change the calibration coefficients to minimize the standard error and to eliminate bias of the ME predicted versus actual measured data.

If the ME software is accurately predicting the measured distress, a graph of the predicted versus measured distress would fall close to a 45 degree line, also known as the line-of-equality. An example is shown in Figure 6-1. The distance each point is away from the line-of-equality is the error. The statistical description of the error of the predictions for the entire population is known as the standard error. An example is shown in Figure 6-1. Bias occurs when the data points of the graph are systematically over or under the line-of-equality. An example is shown in Figure 6-2.

The results of the calibration research projects can be found in research report RC-1595, *Preparation for Implementation of the Mechanistic-Empirical Pavement Design Guide in Michigan, Part3: Local Calibration and Validation of the Pavement-ME Performance Models* and SPR-1668, *Recalibration of Mechanistic-Empirical Rigid Pavement Performance Models and Evaluation of Flexible Pavement Thermal Cracking Model*. Note that the first research project calibration was based on version 2.0 of the ME software and the following research project was based on version 2.3. Calibration results for version 2.3, concrete pavements are not used due to the global coefficient ME thicknesses having less bias than the calibration thicknesses as compared to AASHTO 1993 thicknesses. This is likely due to the limited amount of pavement sections and distress data points to calibrate to. Additional sections and more data points should improve the calibration results, so future recalibration will be considered. Also, note that the later research project improved the asphalt calibration input for Thermal Fracture, Level 1 K per the HMA top course binder low temperature performance grade (PG). This research found that the calibration input for Thermal Fracture is greatly impacted by the HMA top course binder grade. Per MDOT review of the research findings, the most practical change was when the HMA top course low temperature PG was at -34. Therefore, if the HMA top course uses a -34 binder grade, then the Level 1 K input is 0.625, otherwise for all other grades, use 0.75.

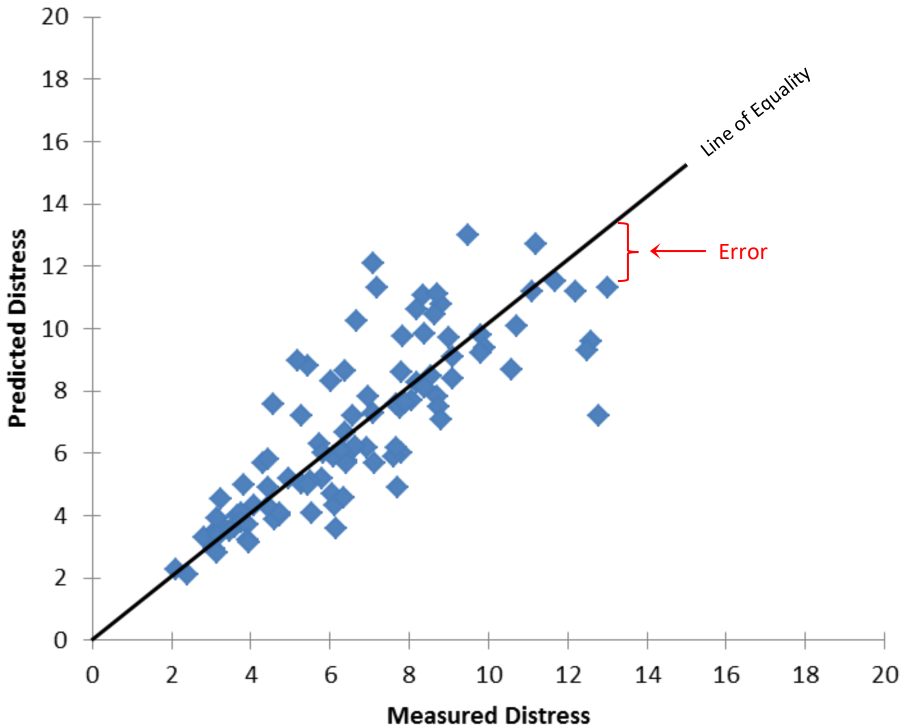



**Figure 6-1. Plot of Predicted vs. Measured**

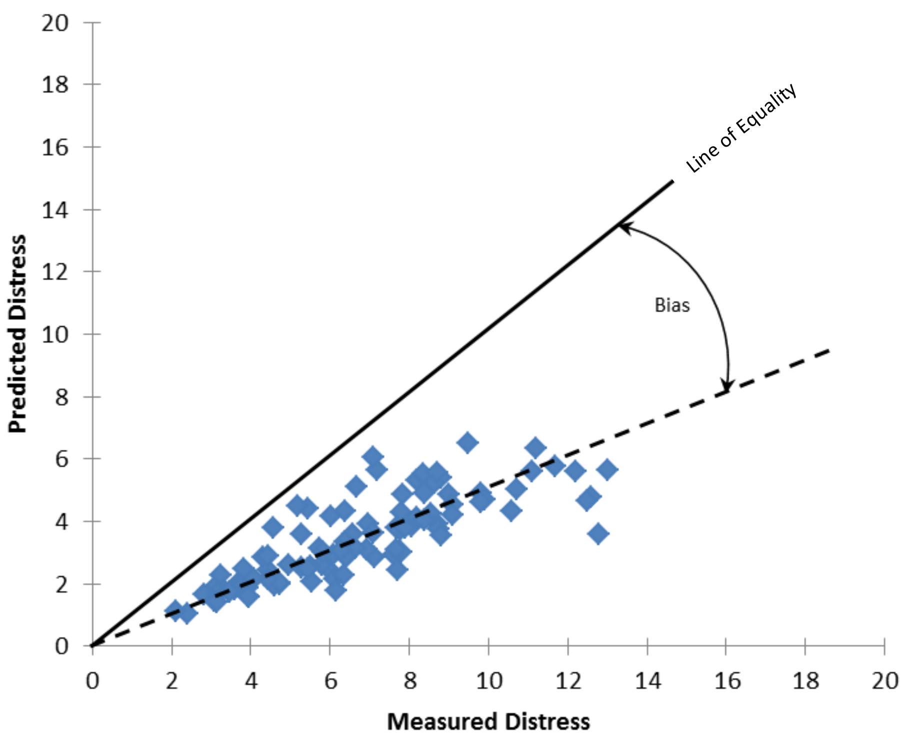



**Figure 6-2. Plot of Predicted vs. Measured Showing Bias**

## 6.2 – Calibration Inputs

The values listed in Tables 6-1 through 6-4 should be entered in the appropriate tab under the 'ME Design Calibration Factors' folder in the Explorer Pane. To open a calibration factor tab, double-click its node. Be sure to click the 'Save Changes to Calibration' button for each tab that had changes (see Figure 6-3). Any new projects that are opened after the changes are saved, will utilize these values.


**Figure 6-3. Available Buttons on the Calibration Factor Tabs**

When a project is first created, it pulls in the calibration factors for that design type from the appropriate tab in the 'ME Design Calibration Factors' folder and stores it in the 'Project Specific Calibration Factors' folder for that project. The example in Figure 6-4 shows a JPCP reconstruct project, so only the 'New Rigid' factors are stored for the project.

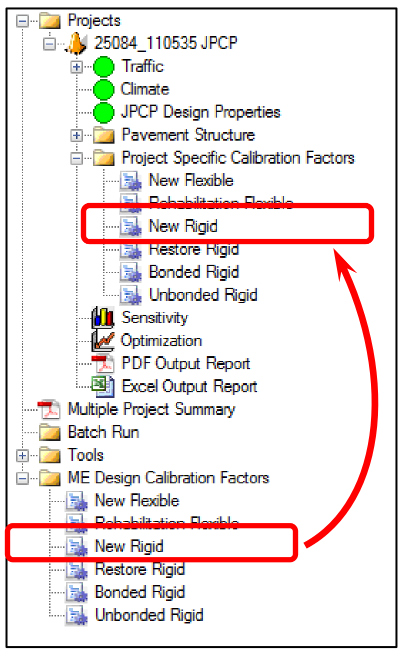



**Figure 6-4. Storing of Project Specific Calibration Factors at Project Creation**

Previously created projects can be updated to the new calibration factors. Open the projects that require updating. Open the appropriate tab from the 'ME Design Calibration Factors' folder (e.g. New Flexible for new/reconstruct asphalt projects) and click the 'Update Open Projects' button (see Figure 6-3).

To restore the software default calibration factors for a design type, open the appropriate tab and click the 'Restore Calibration Defaults' button (see Figure 6-3). All newly created projects of that design type will use the software default calibration factors unless they are changed again.

# Chapter 7 – Traffic Inputs

**Table 7-1. Recommended Traffic Related Inputs**

| Input | | | Units | Recommended Value |
|---|---|---|---|---|
| AADTT | **Two-way AADTT** | | **trucks/ day** | **Actual** |
| | Number of lanes | | | Proposed |
| | Percent trucks in design direction | | % | First Choice: Actual from PTR<br>Second Choice: Actual from Short Term Data<br>Third Choice: 51%/100% (two-way/one-way) |
| | Percent trucks in design lane | | % | First Choice: Actual from PTR<br>Second Choice: Actual from Short Term Data<br>Third Choice: Values/formulas established from WIM data (see Section 7.4.1 – AADTT) |
| | Operational speed | | mph | For mainline routes, use:<br>• The lowest posted speed limit for trucks within the project limits (truck speed max is 65 MPH).<br>For ramps that are not freeway to freeway, use:<br>• Use 30 MPH unless a warning sign speed limit can be used. |
| Traffic Capacity | Traffic capacity cap | Enforce highway capacity limits | | Leave checkbox unselected for 'Not enforced' (do not cap traffic growth) *(software default)* |
| | | Annual average daily traffic excluding trucks | | N/A |
| | | Non-truck linear traffic growth rate | % | N/A |
| | | Highway facility type | | N/A |
| | | Traffic signal | | N/A |
| | | Highway terrain type | | N/A |
| | | Rural or urban highway environment | | N/A |
| | | User-specified capacity limit | | N/A |
| Axle Configuration | Average axle width | | feet | 8.5 *(software default)* |
| | Dual tire spacing | | inches | 12 *(software default)* |
| | Tire pressure | | psi | 120 *(software default)* |
| | Tandem axle spacing | | inches | 51.6 *(software default)* |
| | Tridem axle spacing | | inches | 49.2 *(software default)* |
| | Quad axle spacing | | inches | 49.2 *(software default)* |
| Lateral Wander | Mean wheel location | | inches | 18 *(software default)* |
| | Traffic wander standard deviation | | inches | 10 *(software default)* |
| | Design lane width | | feet | Plan width between paint lines |

| Input | | Units | Recommended Value |
|---|---|---|---|
| Wheelbase | Average spacing of short axles | feet | 12 *(software default)* |
| | Average spacing of medium axles | feet | 15 *(software default)* |
| | Average spacing of long axles | feet | 18 *(software default)* |
| | Percent trucks with short axles | % | 17 *(software default)* |
| | Percent trucks with medium axles | % | 22 *(software default)* |
| | Percent trucks with long axles | % | 61 *(software default)* |
| Vehicle Class Distribution and Growth | Distribution | % | First Choice: Actual from PTR<br>Second Choice: Actual from Short Term Data<br>Third Choice: Cluster avg. (see APPENDIX B.1)<br>Fourth Choice: Non-Freeway/Freeway Statewide average (see APPENDIX B.1) |
| | Growth Rate | % | First Choice: Estimated value from PTR<br>Second Choice: Estimated from Short Term (same for all vehicle classes) |
| | Growth Function | | Compound (for all vehicle classes) |
| Monthly Adjustment | **Monthly Adjustment (Class / Month)** | | **First Choice: Actual from PTR**<br>**Second Choice: Actual from Short Term Data**<br>**Third Choice: Cluster avg. (see APPENDIX B.2)**<br>**Fourth Choice: Non-Freeway/Freeway Statewide average (see APPENDIX B.2)** |
| Axles Per Truck | Axles Per Truck (Axle Distribution / Class) | | Statewide average (see APPENDIX B.3) |
| Hourly Adjustment | **Hourly Adjustment (% AADTT / Hour)** | **%** | **First Choice: Actual from PTR**<br>**Second Choice: Actual from Short Term Data**<br>**Third Choice: Cluster avg. (see APPENDIX B.4)**<br>**Fourth Choice: Non-Freeway/Freeway Statewide average (see APPENDIX B.4)** |
| Single Axle Distribution | **Single Axle Distribution (Weight / Class / Month)** | **%** | **First Choice: Actual from PTR**<br>**Second Choice: Cluster average (see APPENDIX B.5)**<br>**Third Choice: Non-Freeway/Freeway Statewide average (see APPENDIX B.5)** |
| Tandem Axle Distribution | **Tandem Axle Distribution (Weight / Class / Month)** | **%** | **First Choice: Actual from PTR**<br>**Second Choice: Cluster average (see APPENDIX B.6)**<br>**Third Choice: Non-Freeway/Freeway Statewide average (see APPENDIX B.6)** |
| Tridem Axle Distribution | **Tridem Axle Distribution (Weight / Class / Month)** | **%** | **First Choice: Actual from PTR**<br>**Second Choice: Cluster average (see APPENDIX B.7)**<br>**Third Choice: Non-Freeway/Freeway Statewide average (see APPENDIX B.7)** |
| Quad Axle Distribution | **Quad Axle Distribution (Weight / Class / Month)** | **%** | **First Choice: Actual from PTR**<br>**Second Choice: Cluster average (see APPENDIX B.8)**<br>**Third Choice: Non-Freeway/Freeway Statewide average (see APPENDIX B.8)** |

***Bold** = sensitive input

## 7.1 – Introduction

Traffic inputs allow the software to estimate the loads that are applied to a pavement and the frequency with which those given loads are applied throughout its design life. Traffic inputs are defined by the project segment truck traffic characteristics, obtained from weigh-in-motion (WIM) or classification sites, also known as permanent traffic recorders (PTR). Projects that do not have a WIM or classification site nearby utilize short term data (typically 48 hour surveys), traffic clusters, or statewide averages. The steps to obtain project-specific traffic inputs are outlined in Section 7.2 – Obtaining Traffic Inputs (Traffic Request Procedure) and the traffic cluster method is explained in Section 7.3 – Traffic Cluster Method.

To convert PTR data into acceptable ME software data requirements, an external application, Prep-ME 3.0 was developed as part of the Transportation Pooled Fund study TPF-5(242). Prep-ME is primarily designed to help store, process, and analyze traffic data, and converts that data into acceptable input files for the ME software. The input files are stored in a designated folder location for use by MDOT designers. This location is identified in Chapter 3 – Design Process. The Pavement Management Section is responsible for Prep-ME operation and maintains the PTR input files for the ME software.

In the ME software, traffic related inputs are located in the Traffic tab and Axle Distribution tabs under the project folder of the Explorer menu. View the Axle Distribution tabs by expanding the Traffic drop-down node in the Explorer menu. Traffic tab inputs are outlined in Section 7.4 – Traffic Tab Inputs and Axle Load Distribution table inputs are outlined in Section 7.5 – Axle Load Distribution Tabs.

## 7.2 – Obtaining Traffic Inputs (Traffic Request Procedure)

To obtain traffic related ME software inputs, use the following steps:

1. Submit a Traffic Analysis Request (TAR), Form 1730 to request the necessary traffic inputs for an ME design.
    a. This form is sent to the Statewide & Urban Travel Analysis Section (SUTA), of the Bureau of Transportation Planning, as noted on the form.
    b. In the form:
        i. Check boxes ‘Equivalent Single Axle Loadings (ESAL)’ and ‘M-E Inputs for Pavement Design’ to indicate the ESAL and ME information requests.
            1. ***NOTE**: ESAL information is not an input for the ME software, but is needed for preliminary designs using AASHTO 1993, and for HMA mix selection.*
        ii. Identify the project location, year of construction, and design life.
        iii. Identify if ramp data is needed in the “REMARKS/OTHER ANALYSES” area.
2. The SUTA Section utilizes the information from the submitted form to determine if a WIM or classification site is nearby and representative of the project location. Based on that determination, the **SUTA Section provides** the following information in a memo to the requestor (***NOTE**: (#) identifies the order of option to use per availability*):
    a. If a usable WIM site is nearby and representative of the project location, use the WIM site information to provide:

i. ESAL (initial and total)
ii. Two-way Average Annual Daily Truck Traffic (AADTT or CADT)
iii. Traffic Growth Rate
iv. Percent trucks in design direction
v. Percent trucks in design lane
vi. WIM # for:
    1. *Monthly Adjustment (distribution factors)*
    2. *Hourly Adjustment (distribution factors)*
    3. *Vehicle (Truck) Class Distribution*
    4. *Single, Tandem, Tridem, and Quad Axle Distribution*

b. If a WIM site is not appropriate, but a classification site is nearby and representative of the project location, then use the classification site information to provide:
    i. ESAL (initial and total)
    ii. Two-way AADTT or CADT
    iii. Traffic Growth Rate
    iv. Percent trucks in design direction
    v. Percent trucks in design lane
    vi. Classification site # for:
        1. *Monthly Adjustment (distribution factors)*
        2. *Hourly Adjustment (distribution factors)*
        3. *Vehicle (Truck) Class Distribution*
    vii. Cluster(1) or Freeway/Non-Freeway Statewide Average(2) for:
        1. *Single, Tandem, Tridem, and Quad Axle Distribution*

c. If a WIM site or classification site are not available, then provide short term data for:
    i. ESAL (initial and total)
    ii. Two-way AADTT or CADT
    iii. Traffic Growth Rate
    iv. Short Term Data(1) or 51%/100% (two-way/one-way)(2) for:
        1. *Percent trucks in design direction*
    v. Short Term Data(1) or Value/Formula (see Section 7.4.1 - AADTT)(2) for:
        1. *Percent trucks in design lane*
    vi. Short Term Data(1), Cluster(2), or Freeway/Non-Freeway Statewide Average(3) for:
        1. *Hourly Adjustment (distribution factors)*
        2. *Vehicle (Truck) Class Distribution*
    vii. Cluster(1) or Freeway/Non-Freeway Statewide Average(2) for:
        1. *Monthly Adjustment (distribution factors)*
        2. *Single, Tandem, Tridem, and Quad Axle Distribution*

d. If ramp information was also requested, then SUTA should also provide the following ramp information using short term data for:
    i. ESAL (initial and total)
    ii. One-way AADTT or CADT
    iii. Short Term Data(1) or same as mainline(2) for:

        1. *Hourly Adjustment (distribution factors)*
        2. *Vehicle (Truck) Class Distribution*
    iv. Do <u>not</u> provide the following for ramps:
        1. *Traffic Growth Rate (same as mainline)*
        2. *Percent trucks in design direction (this is 100%)*
        3. *Percent trucks in design lane (this is 100%)*
        4. *Monthly Adjustment (same as mainline)*
        5. *Single, Tandem, Tridem, and Quad Axle Distribution (same as mainline)*

3. **The designer** utilizes the information provided in the TAR memo to populate the appropriate inputs in the ME software, (see Sections 7.4 – Traffic Tab Inputs and 7.5 – Axle Load Distribution Tabs). PTR, Cluster, and Freeway/Non-Freeway Statewide Average inputs can be imported using .XML files or copied from Excel file found on the Construction Field Services Division common server in the 'ME Pvmt Design\Traffic' folder. Cluster and freeway/non-freeway statewide average values can also be found in APPENDIX B – Traffic Inputs.
    a. Inputs that the designer will determine and provide include the following:
        i. Number of Lanes
        ii. Operational speed
        iii. Design lane width
    b. The remaining traffic related ME software inputs are non-changing values. The remaining inputs are outlined as follows:
        i. Axles Per Truck (statewide average)
        ii. Growth Function (always compound)
        iii. Average axle width (ME software default)
        iv. Dual tire spacing (ME software default)
        v. Tire pressure (ME software default)
        vi. Tandem axle spacing (ME software default)
        vii. Tridem axle spacing (ME software default)
        viii. Quad axle spacing (ME software default)
        ix. Mean wheel location (ME software default)
        x. Traffic wander standard deviation (ME software default)
        xi. Average spacing of short axles (ME software default)
        xii. Average spacing of medium axles (ME software default)
        xiii. Average spacing of long axles (ME software default)
        xiv. Percent trucks with short axles (ME software default)
        xv. Percent trucks with medium axles (ME software default)
        xvi. Percent trucks with long axles (ME software default)

For further details and instruction on cluster number selection, see Section 7.3 – Traffic Cluster Method. For further details and information on traffic related inputs and how to enter them, see Sections 7.4 – Traffic Tab Inputs and 7.5 – Axle Load Distribution Tabs.

**Table 7-2. Summary of Information Provided in TAR**

| | a. If a usable WIM site is nearby and representative of the project location: | b. If a WIM site is not available, but a classification site is nearby and representative: | c. If a WIM site or classification site are not available: | d. If ramp (not Fwy to Fwy) info was requested, also provide the following ramp information: |
|---|---|---|---|---|
| **Two-way AADTT or CADT** | Value from WIM site | Value from class site | Value from Short term data | Value from Short term data |
| **Traffic Growth Rate** | Value from WIM site | Value from class site | Value from Short term data | *Do not provide (same as mainline)* |
| **Percent trucks in design direction** | Value from WIM site | Value from class site | Value from:<br>1. Short term data<br>2. 51%/100% (2-way/1-way) | *Do not provide (this is 100%)* |
| **Percent trucks in design lane** | Value from WIM site | Value from class site | Value from:<br>1. Short term data<br>2. Value/Formula (see Section 7.4.1 - AADTT) | *Do not provide (this is 100%)* |
| **Monthly Adjustment** | WIM # | Classification site # | 1. Cluster<br>2. F/NF State Avg. | *Do not provide (same as mainline)* |
| **Hourly Adjustment** | WIM # | Classification site # | 1. Short Term Data<br>2. Cluster<br>3. F/NF State Avg. | 1. Short term data<br>2. Same as mainline |
| **Vehicle (Truck) Class Distribution** | WIM # | Classification site # | 1. Short Term Data<br>2. Cluster<br>3. F/NF State Avg. | 1. Short term data<br>2. Same as mainline |
| **Single, Tandem, Tridem, & Quad Axle Distribution** | WIM # | 1. Cluster<br>2. F/NF State Avg. | 1. Cluster<br>2. F/NF State Avg. | *Do not provide (same as mainline)* |
| **ESAL (initial & total)** | Estimated per CADT | Estimated per CADT | Estimated per CADT | Estimated per CADT |

**NOTE:** F is “Freeway” and NF is “Non-Freeway”

## 7.3 – Traffic Cluster Method

Traffic clustering is a fairly common practice in traffic modeling. A cluster is a group of WIM or classification sites that are very similar for a particular ME input. The ME input for a cluster is the average from the group of PTR sites in the cluster. Different clusters can be used for different inputs. For example, a set of sites that are clustered for one input may not be clustered together for other inputs. Specifics about the roadway location in question are compared with typical roadway details within each cluster. The cluster that the roadway location is most similar to is the cluster that should be used. The Statewide Transportation Planning Division will identify whether clusters are an appropriate use for a project.

The MDOT research report # SPR-1678, defined potential clusters for Michigan ME software input. This report provided cluster inputs for Truck Traffic Class Distribution, Hourly Adjustment, Monthly Adjustment, and Single, Tandem, Tridem, and Quad Axle Distributions. Selection based on the project site characteristics is used to determine the most appropriate cluster group for each one of these inputs. The following roadway/traffic characteristics per their listed value categories were used to group the WIM sites and establish the clusters:

- Vehicle Class 9%
  - Less than 45%
  - 45% to 70%
  - More than 70%
- Rural/Urban designation (per Adjusted Census Urban Boundary Codes)
  - Urban
  - Rural
- CADT (one-way)
  - Less than 1000
  - 1000 to 3000
  - More than 3000
- Corridors of Highest Significance (COHS) designation
  - National
  - Regional
  - Statewide
- Number of lanes
  - 2
  - 3
  - 4 or more

Subsequently, the cluster groups for each ME input are established per the optimal combinations of roadway/traffic characteristics shown in Table 7-3 below. The optimal combination was determined by the characteristics that provided the most dissimilar cluster groups and had at least 1 WIM site available per each cluster group.

**Table 7-3. ME Input Optimal Characteristics for Clusters**

| ME Input | Optimal Characteristics | |
|---|---|---|
| Truck Traffic Class Distribution | Vehicle Class 9% | Rural/Urban designation |
| Hourly Adjustment | Vehicle Class 9% | Rural/Urban designation |
| Monthly Adjustment | Vehicle Class 9% | Rural/Urban designation |
| Single Axle Distribution | COHS | Rural/Urban designation |
| Tandem Axle Distribution | Number of lanes | Rural/Urban designation |
| Tridem Axle Distribution | COHS | Rural/Urban designation |
| Quad Axle Distribution | COHS | Rural/Urban designation |

The location characteristic values for Vehicle Class 9%, Rural/Urban, COHS, and number of lanes are from MDOT database information. To consolidate this data per location, a spreadsheet, 'Level 2B ME Input Data.xlsx' was developed. Spreadsheet locations are identified by their Michigan Physical Reference (PR) number and milepoints. Note that the cluster selection process is contingent upon all roadway characteristic values being available. If a characteristic is unavailable, then freeway or non-freeway statewide averages should be recommended. The spreadsheet is maintained by the Pavement Management Section.

To quickly determine the cluster group and ME inputs, a spreadsheet, 'Level 2B ME Inputs.xlsx' was developed. The spreadsheet incorporates the cluster groups so that when the user selects the roadway characteristic categories, it will identify the appropriate cluster and ME inputs. The spreadsheet is maintained by the Pavement Management Section.

Location characteristic values for cluster identification will be performed by Statewide Transportation Planning and reported in the TAR memo. The designer will use this information to determine the cluster and associated ME inputs. The process for determining the cluster and associated ME inputs using the 'Level 2B ME Inputs.xlsx' spreadsheet is as follows:

1. For the roadway segment of interest, identify and obtain:
   a. Vehicle class 9%, rural or urban designation, COHS designation, and number of lanes
      i. ***NOTE**: This information can be obtained using the 'Level 2B ME Input Data.xlsx' spreadsheet. Alternatively, vehicle class 9% and CADT (one-way) can be obtained using PTR or short-term data.*
2. Open up the 'Level 2B ME Inputs.xlsx' spreadsheet
3. Select the first tab
   a. Select the appropriate category for each roadway/traffic characteristic, starting in cell B2.
4. Cluster ME input data will be shown in the tables below, (still in the first tab).
5. Copy the necessary ME inputs from the spreadsheet table(s) and paste into the corresponding ME table(s).

See APPENDIX B – Traffic Inputs for inputs of the cluster groups.

## 7.4 – Traffic Tab Inputs

Traffic inputs are accessed by selecting the Traffic tab under the project folder of the Explorer menu. This tab can also be accessed by selecting the tire shown in the Pavement Structure display area of the main Project tab.

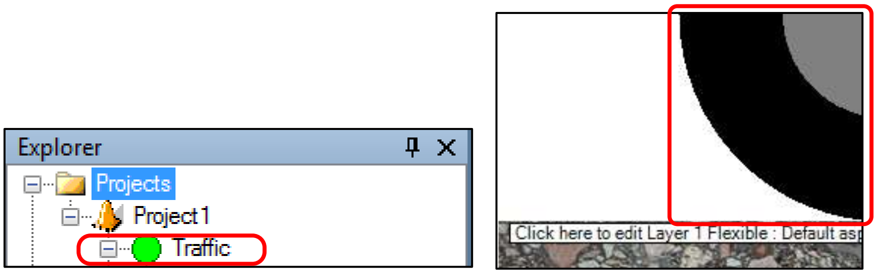



**Figure 7-1. Traffic Tab Access Locations**

Traffic tab areas (drop-down headings and tables):

- AADTT
- Traffic Capacity
- Axle Configuration
- Lateral Wander
- Wheelbase
- Vehicle Class Distribution and Growth
- Monthly Adjustment
- Axles Per Truck
- Hourly Adjustment (concrete designs only)

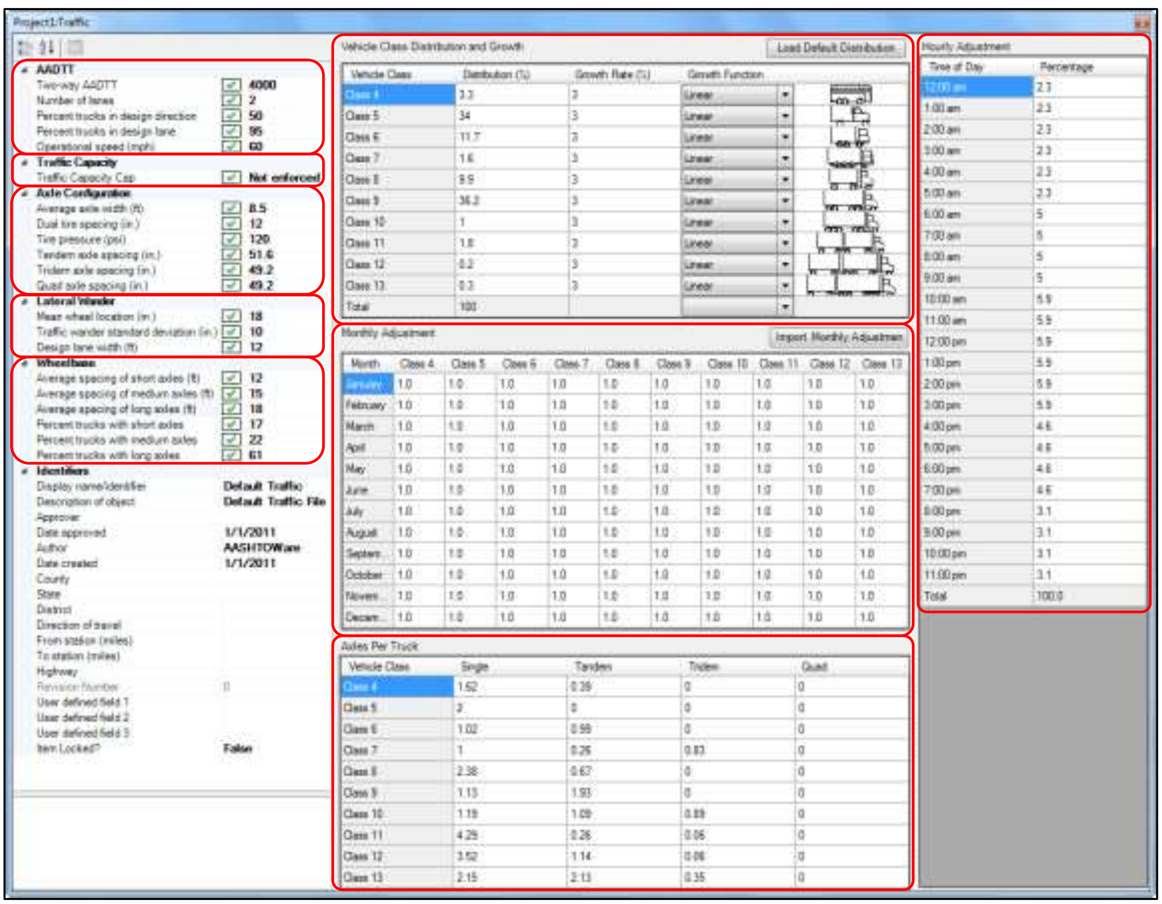


**Figure 7-2. Traffic Tab Areas (Headings and Tables)**

**Before starting** to enter information or editing inputs of the Traffic tab, use the TAR memo (see Section 7.2 – Obtaining Traffic Inputs (Traffic Request Procedure)) to identify the recommended inputs. If a PTR site or freeway/non-freeway statewide average is identified for either input, import the appropriate XML file. Do this by right-clicking the Traffic tab in the Explorer menu. An option list will appear. Select the option 'Import XML File'. Based on the identified option, use the designated folder location (identified in Chapter 3 – Design Process) to locate the appropriate XML file. After opening this file, the inputs will be populated with the associated data. After importing the appropriate XML file, information identified in the TAR memo or by the designer can be manually entered (e.g., Two-way AADTT, Number of lanes, Lane Width, etc.). **It is very important to first import a Traffic tab XML file before making manual changes because the import will overwrite all previously entered information**. Note that a Traffic tab XML file import is independent from an Axle Load Distribution tab import and they do not affect each other (see Section 7.5 – Axle Load Distribution Tabs).

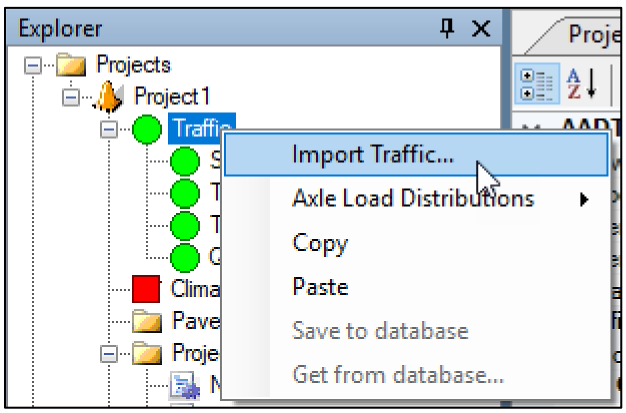



**Figure 7-3. How to Import PTR or Freeway/Non-Freeway Statewide Values into Traffic Tab**

Alternatively, if only cluster or short term data is referenced in the TAR, then copy and paste this information into the corresponding tables in Pavement ME. The import function is not needed, nor concern about order of operations per adding the data to Pavement ME.

### 7.4.1 – AADTT

Two-way AADTT

Enter the average annual daily truck traffic (AADTT) of the project base year in both directions of travel. Trucks are represented by FHWA Vehicle Classes 4 through 13. AADTT is also known as commercial average daily traffic (CADT). In some unique situations, one-way AADTT may be appropriate for this input. For example, ramp designs require one-way AADTT because ramps do not have dual directions. The distress outputs are sensitive to this input. This input will be provided in the TAR memo.

Number of lanes

Enter the proposed number of mainline through lanes for the direction with the fewest number of lanes. Lanes that are not mainline through lanes should not be included in the number of lanes. This includes turn lanes, weave/merge lanes, etc. This input should be identified by the designer.

Percent trucks in design direction

Enter the percentage of trucks (from the entire two-way AADTT count) that is expected to travel in the design direction. The design direction is the direction expected to carry the most load, (typically this is the direction with the fewest number of lanes). Note that although this value is close to 50 percent, it is not always, especially in cases where truck traffic does not use the same route for the outbound and return trips. When one-way AADTT is provided, this input should be 100%.

If a PTR is representative of the project location, then data from that PTR should be used for this input. If a PTR is not available, then data from short term counts should be used, (if available). If actual data is not available, then use 51%, (unless one-way AADTT is utilized, then use 100%). This input will be provided in the TAR memo.

The third choice value of 51% was derived from the average of all WIM data from March and June of 2013. It was found that directional distribution is relatively consistent amongst the WIM sites.

Percent trucks in design lane

Enter the percentage of trucks in the design direction expected to use the design lane (typically the outer rightmost mainline lane). See 'Percent trucks in design direction' above for design direction information. The design lane is a mainline through lane. Lanes that are not mainline through lanes should not be included in the number of lanes. This includes turn lanes, weave/merge lanes, etc.

The input value is 100 if there is only one lane in the design direction. For segments with more than one lane in the design direction, the input value should come from a PTR. If a PTR is not available, data from short term counts should be used, (if available). If actual data is not available, utilize the values or formulas listed in the table below:

**Table 7-4. Percent Trucks in Design Lane Input for Segments Without PTR or Short-Term Counts**

| AADT (all vehicles) | 2 Lanes (per design direction) | ≥ 3 Lanes (per design direction) |
|---|---|---|
| 0 – 25,000 | 96% | 83% |
| 25,001 – 50,000 | 92% | 77% |
| > 50,000 | % = 98 - 0.000152*(AADT) | % = 86 - 0.000247*(AADT) |

Formulas are based on average annual daily traffic (AADT) and PTR data. The formulas are based on all vehicles, rather than truck vehicles only because it was determined that the total number of vehicles had a greater influence and better predictive quality for truck lane distribution. This input will be provided in the TAR memo.

The values and formulas established in the table above were derived from averages of Michigan WIM data from March and June of 2013. It should be noted that some WIM sites were considered outliers and were eliminated if geometric changes or other unique conditions occurred that caused traffic volumes and patterns to fluctuate. It was found that in general, there is more variation when there are more lanes, but this may be due to fewer WIM sites on three and four lane roadways. Also, at lower traffic levels, the values from the formulas do not vary greatly. This input does not significantly impact distress outputs, and it was determined that the formulas are adequately representative of most roadways in Michigan.

<u>Operational speed (mph)</u>
Enter the lowest posted truck speed limit for the length of the roadway. Posted non-commercial (not truck) speed limits are listed in the MDOT Lane Mile Inventory (LMI) database file. Speed limits in this file will match the truck speed limit, unless the speed is 65 MPH or greater. In these cases, use 65 MPH. This input should be no more than the maximum truck speed limit in Michigan, 65 miles per hour. For ramps that are not freeway to freeway, use 30 MPH unless a warning sign speed limit can be determined. If so, use this speed. For ramps that are freeway to freeway, use the lower truck speed limit of the two freeways, unless a warning sign speed limit can be determined. If so, use this speed. This ME input should be identified by the designer.

Operational speed reflects the time traffic is moving and does not incorporate stopped time. Currently, it is not clear how to incorporate congestion into operational speed. For example, the operational speed may be 60 miles per hour for most of the day, but at peak hour, the speed may be 30 miles per hour. Consideration was given to lowering the operational speed if the roadway has a low level of service, but data could not be found to determine this speed. Ultimately, it was determined that congested situations would be reflected with lower growth rates, so lowering the operational speed is not necessary.

### 7.4.2 – Traffic Capacity

<u>Traffic Capacity Cap</u>
This input allows enforcement of a cap on estimated future traffic volumes, based on Highway Capacity Manual (HCM) limits, so that the capacity is not exceeded. The two options include “enforced” or “not enforced.” The ME software default option is ‘not enforced’. Use the default option by leaving the ‘Enforce highway capacity limits’ checkbox unselected, so that ‘not enforced’ is used. Further data entry is not needed because “enforced” is not used. The ‘Enforce highway capacity limits’ checkbox is found in the Traffic Capacity box that appears when the drop-down arrow is clicked.

Selecting “enforced” allows the user to enforce a cap on estimated traffic volumes used in the design/analysis so that the expected highway capacity is not exceeded. If “enforced” was selected, then a user-specified capacity limit would need to be identified. Alternatively, the capacity limit can be calculated in the ME software if the user enters annual average daily traffic excluding trucks, non-truck linear traffic growth rate, highway facility type, traffic signal, highway terrain type, and rural/urban highway environment.

Enforcing the traffic capacity is not used because it was determined that if there are capacity concerns, they would be addressed in other areas. For example, if a roadway is already near capacity (highly developed), that would probably lead to a lower traffic growth rate. Thus, a capacity issue would be reflected in the growth rate to some extent. Also, for some Michigan road segments, it was found that actual traffic volumes were greater than the calculated capacity (based on HCM equations).

### 7.4.3 – Axle Configuration

Average axle width (ft)
Enter the distance between two outside edges of an axle. Use the ME software default value of 8.5 ft.

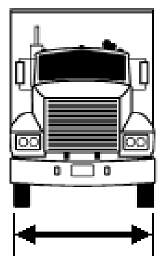


**Figure 7-4. Average Axle Width Example**

Dual tire spacing (in.)
Enter the distance between the centers of a dual tire. Use the ME software default value of 12 in.

Tire pressure (psi)
Enter the hot inflation pressure of the tires. It is assumed to be 10% above cold inflation pressure. Use the ME software default value of 120 psi.

Tandem axle spacing (in.)
Enter the center-to-center longitudinal spacing between two consecutive axles in a tandem configuration. Use the ME software default value of 51.6 in.

MDOT has previously assessed this value at 4.3 ft (51.6 in), which agrees with the default value.

Tridem axle spacing (in.)
Enter the center-to-center longitudinal spacing between two consecutive axles in a tridem configuration. Use the ME software default value of 49.2 in.

Quad axle spacing (in.)
Enter the center-to-center distance between two consecutive axles in a quad configuration. Use the ME software default value of 49.2 in.

### 7.4.4 – Lateral Wander

Mean wheel location (in.)
Enter the distance from the outer edge of the wheel to the edge of the travel lane pavement marking, (not the longitudinal joint in widened lane situations). Use the ME software default value of 18 in.

There is limited data to support a different value from the default value. Research revealed only 3 locations in Michigan with data related to this input. This dataset is not large enough to be statistically representative of the Michigan road network.

Traffic wander standard deviation (in.)
Enter the standard deviation from the mean wheel location. The standard deviation is used to estimate the number of axle load repetitions over a single point. Use the ME software default value of 10 in.

Similar to the Mean Wheel Location input, there is limited data to support changing the default value.

Design lane width (ft)
Enter the actual or design width of the design lane (typically the outer rightmost mainline lane). The software allows input of 10' to 15', but designers should not use more than 12'. This input should be identified by the designer.

This input does not indicate widened slabs. Use the 'Widened slab' input in JPCP Design Properties (see Section 10.2 – JPCP Design Properties Tab Inputs) to indicate a widened slab.

### 7.4.5 – Wheelbase

Wheelbase is the distance between the front and rear axles of the tractor only. There are three categories of wheelbase: short, medium, and long.

Average spacing of short axles (ft)
Enter the average longitudinal spacing of short axles. Use the ME software default value of 12 ft.

Average spacing of medium axles (ft)
Enter the average longitudinal spacing of medium axles. Use the ME software default value of 15 ft.

Average spacing of long axles (ft)
Enter the average longitudinal spacing of long axles. Use the ME software default value of 18 ft.

Percent trucks with short axles
Enter the percentage of Class 8 through 13 trucks with short axles. Use the ME software default value of 17 percent.

Percent trucks with medium axles

Enter the percentage of Class 8 through 13 trucks with medium axles. Use the ME software default value of 22 percent.

Percent trucks with long axles

Enter the percentage of Class 8 through 13 trucks with long axles. Use the ME software default value of 61 percent.

### 7.4.6 – Vehicle Class Distribution and Growth

Distribution (%)

For this column, enter the percentage of each commercial vehicle class. Commercial traffic is defined by FHWA vehicle classifications 4 through 13. The percentage of each commercial vehicle class is based on the total commercial traffic (AADTT), not the total of all traffic (AADT). For example, the percentage shown for vehicle Class 4 is derived from the following equation:

*Class 4 % = (average daily Class 4 traffic volume) / (average daily Class 4 through 13 traffic total volume)*

At the bottom of the Distribution (%) column, the percentage total will be indicated. This total must equal 100 after all percentages are input.

If a PTR is representative of the project location, then data from the appropriate PTR should be used to populate the column. If a PTR is not available, then data from short term counts should be used. If a short term count is not available, then a representative cluster (APPENDIX B.1) should be selected using the required roadway characteristics, (if available). If some cluster roadway characteristics are not available, then Michigan freeway or non-freeway statewide averages (APPENDIX B.1) should be used (per the roadway type). The TAR memo will indicate which option to use and/or the actual distribution.

Growth Rate (%)

For this column, enter the expected annual growth rate, as a percentage, for each of the FHWA vehicle classes, 4 through 13. While the ME software will accept different growth rates for different truck classifications, only one value should be used for all classes. This input is obtained from the TAR memo.

Growth rates are estimated by Statewide Transportation Planning using economic and historic information to populate growth models.

Growth Function

For this column, select compound for the traffic growth function. This is used to compute the growth or decay in truck traffic over time (forecasting truck traffic). All options include:

- None: This option sets traffic volume to remain the same throughout the design life. Do not select this option.

- Linear: This option allows traffic volume to increase by constant percentage of the base year traffic across each truck class growth to happen at the defined rate. Do not select this option.
- Compound: This option allows traffic volume to increase by constant percentage of the preceding year traffic across each truck class. Select this option.

Currently, compound growth is used with growth rates. There is a potential issue if the rate is predicted to change over the design life, but there is no direct way to address this in the ME software.

### 7.4.7 – Monthly Adjustment

Monthly Adjustment Table
In this table, enter the ratio of each vehicle class' average for that month compared to the overall monthly average. The sum of the monthly values for each vehicle class must equal 12.

If a PTR is representative of the project location, then data from the appropriate PTR should be used to populate the table. If a PTR is not available, then a representative cluster (APPENDIX B.2) should be selected using the required roadway characteristics, (if available). If some cluster roadway characteristics are not available, then Michigan freeway or non-freeway statewide averages (APPENDIX B.2) should be used (per the roadway type). The TAR memo will indicate which option to use and/or the actual distribution.

### 7.4.8 – Axles per Truck

Axles per Truck Table
In this table, enter the average number of axles for each FHWA truck class, (4 through 13) for each axle type (single, tandem, tridem, and quad). Use the Michigan statewide averages (see APPENDIX B.3) to populate this table.

### 7.4.9 – Hourly Adjustment

Hourly Adjustment Table
This table is only shown and used in concrete pavement designs. Enter the distribution of truck traffic for each hour of the day. Each value represents the percentage of the overall truck traffic that occurs in that hour. The total of all hourly values must equal 100. Hourly adjustments are also known as hourly distribution factors (HDF).

If a PTR is representative of the project location, then data from the appropriate PTR should be used to populate this table. If a PTR is not available, then data from short term counts should be used. If a short term count is not available, then a representative cluster (APPENDIX B.4) should be selected using the required roadway characteristics, (if available). If some cluster roadway characteristics are not available, then Michigan freeway or non-freeway statewide averages (APPENDIX B.4) should be used (per the roadway type). The TAR memo will indicate which option to use and/or the actual distribution.

### 7.5 – Axle Load Distribution Tabs

Axle distribution (also known as axle load spectra) tables are accessed by selecting the appropriate tab under the Traffic tab of the Explorer menu.

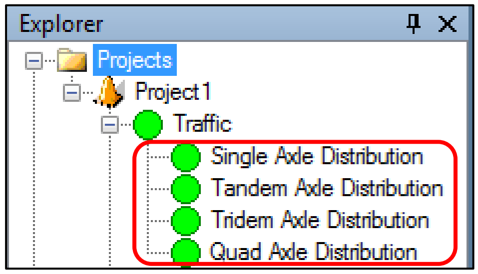



**Figure 7-5. Axle Load Distribution Tabs Access Location**

Axle distribution tabs include the following:

- Single Axle Load Distribution tab (3,000 lb to 41,000 lb bins at 1,000 lb intervals)
- Tandem Axle Load Distribution tab (6,000 lb to 82,000 lb bins at 2,000 lb intervals)
- Tridem Axle Load Distribution tab (12,000 lb to 102,000 lb bins at 3,000 lb intervals)
- Quad Axle Load Distribution tab (12,000 lb to 102,000 lb bins at 3,000 lb intervals)

Each table defines the percentage of the total axle applications of an axle type (single, tandem, tridem, and quad) within each load interval (3,000, 4,000, etc.) per FHWA vehicle class (Classes 4 through 13) for each month of the year. The load interval weights are grouped into equally segmented categories, or "bins". For example, the Single Axle table groups up to 2999 pounds in the 3000 bin, followed by 3000 to 3999 pounds in the 4000 bin, and so on. Each cell represents the percentage of the overall traffic for that vehicle class and month that falls into that weight bin. Below is an example of the Single Axle Load Distribution tab:

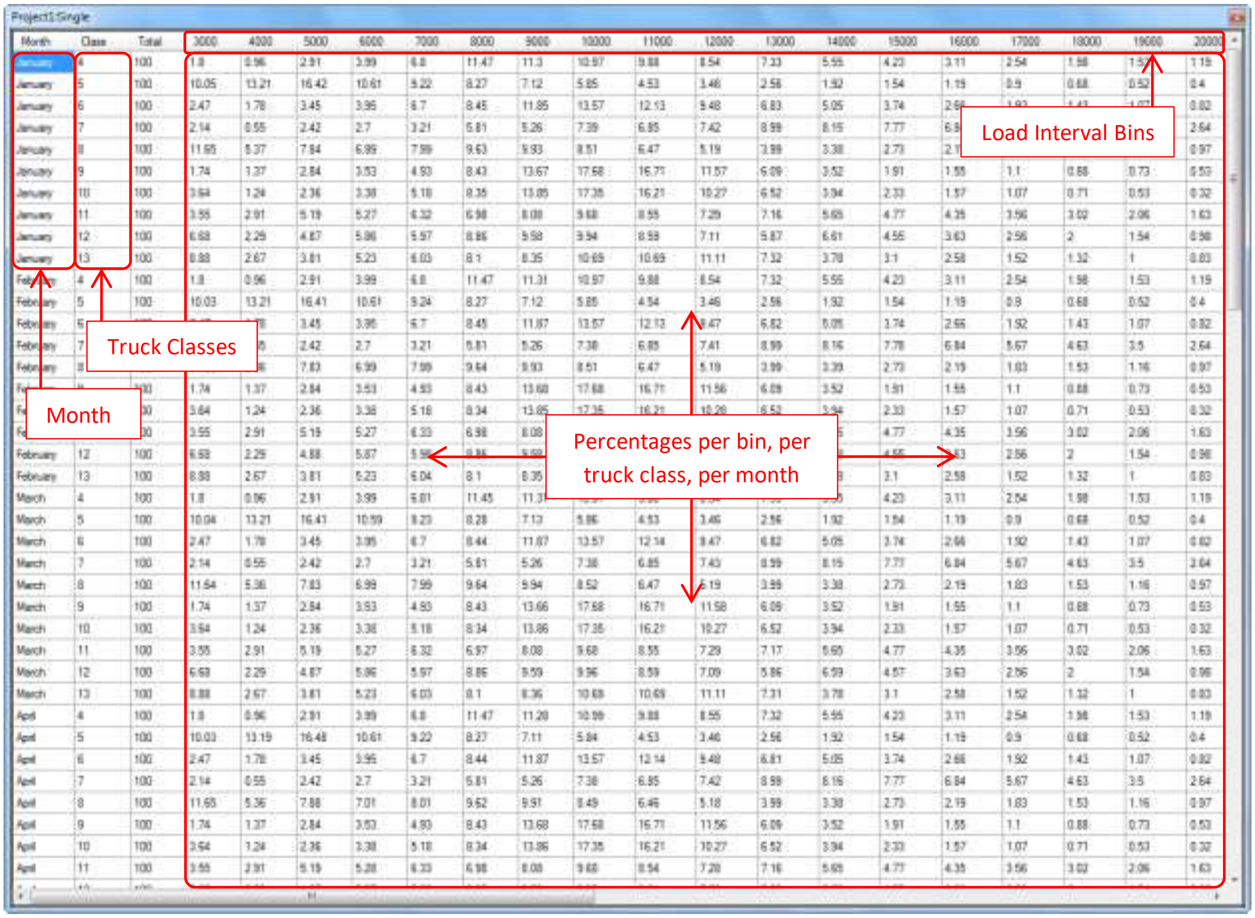



**Figure 7-6. Axle Load Distribution Tab Areas (Single Axle Distribution tab shown)**

To add the appropriate information to the tables, right-click the Traffic tab in the Explorer menu. In the option list, select the option 'Import XML File'. Based on the identified Tandem Axle Load Distribution option (see Section 7.2 – Obtaining Traffic Inputs (Traffic Request Procedure)), use the designated folder location (identified in Chapter 3 – Design Process) to locate the appropriate XML file. After opening this file, all of the Axle Load Distribution tabs will be populated with the appropriate data. **Note that XML files apply to all Axle Load Distribution tabs and will change information in all of them**.

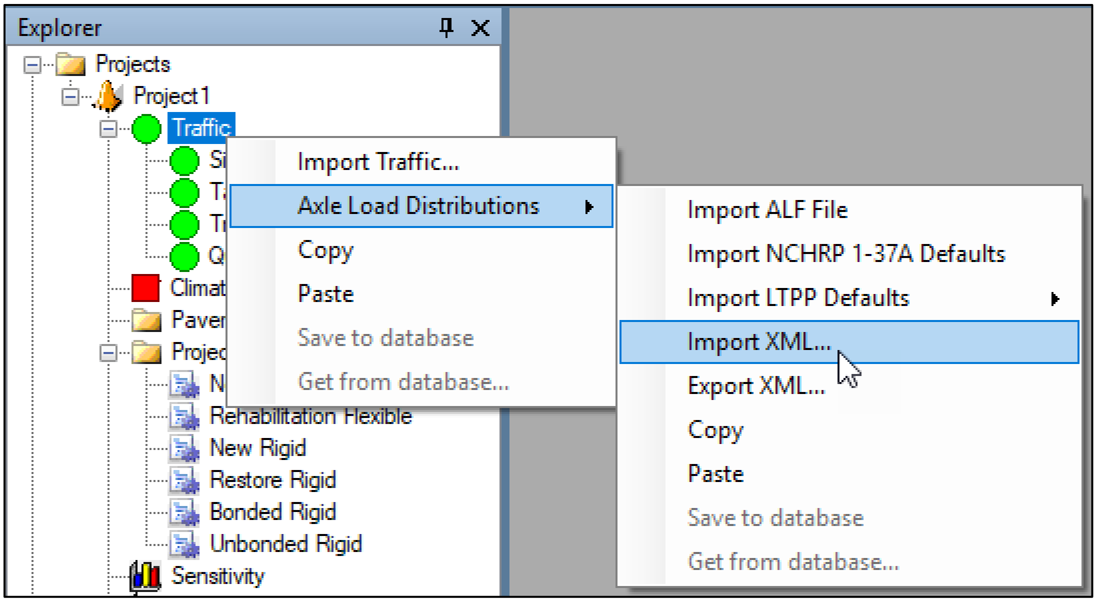



**Figure 7-7. How to Import PTR and Freeway/Non-Freeway Statewide Values to Axle Distribution Tabs**

### 7.5.1 – Single Axle Load Distribution

If a WIM is representative of the project location, then data from the appropriate WIM site should be used to populate the table. If a specific WIM is not available, then a representative cluster (APPENDIX B.5) should be selected using the required roadway characteristics, (if available). If some cluster roadway characteristics are not available, then Michigan freeway or non-freeway statewide averages (APPENDIX B.5) should be used (per the roadway type). The TAR memo will indicate which option to use and/or the actual distribution.

### 7.5.2 – Tandem Axle Load Distribution

If a WIM is representative of the project location, then data from the appropriate WIM site should be used to populate the table. If a specific WIM is not available, then a representative cluster (APPENDIX B.6) should be selected using the required roadway characteristics, (if available). If some cluster roadway characteristics are not available, then Michigan freeway or non-freeway statewide averages (APPENDIX B.6) should be used (per the roadway type). The TAR memo will indicate which option to use and/or the actual distribution.

### 7.5.3 – Tridem Axle Load Distribution

If a WIM is representative of the project location, then data from the appropriate WIM site should be used to populate the table. If a specific WIM is not available, then a representative cluster (APPENDIX B.7) should be selected using the required roadway characteristics, (if available). If some cluster roadway characteristics are not available, then Michigan freeway or non-freeway statewide averages (APPENDIX B.7) should be used (per the roadway type). The TAR memo will indicate which option to use and/or the actual distribution.

### 7.5.4 – Quad Axle Load Distribution

If a WIM is representative of the project location, then data from the appropriate WIM site should be used to populate the table. If a specific WIM is not available, then a representative cluster (APPENDIX B.8) should be selected using the required roadway characteristics, (if available). If some cluster roadway characteristics are not available, then Michigan freeway or non-freeway statewide averages (APPENDIX B.8) should be used (per the roadway type). The TAR memo will indicate which option to use and/or the actual distribution.

# Chapter 8 – Climate Inputs

**Table 8-1. Climate Inputs**

| Input | Value |
|---|---|
| Latitude/Longitude | Center of project location (can be used to locate the closest single weather station) |
| Elevation | Do not use |
| Water Table Depth Type | Annual |
| Water Table Depth | Annual Average Value if known,<br>Otherwise use one of the following:<br>• 2 feet when there is evidence or suspicion of water within 5 feet of top of subgrade<br>• 5 feet in all other cases |
| Climate Station | Closest single weather station |

## 8.1 – Introduction

Pavement ME Design comes with 24 weather stations in Michigan, which are all located at airports. However, five of these stations (Sault Ste. Marie, Alpena, Saginaw, Holland, and Jackson) were missing a month of data, so they could only be used when creating a virtual station (a single project-specific weather station created from the data of multiple weather stations). ME requires climatic data for each hour of each day for all twelve months. The remaining 19 weather stations contained some missing or erroneous data. In addition, the 24 weather stations are not geographically distributed throughout the state. Thus, research was conducted to add 15 weather stations to fill the vacant areas and add historical data. In addition, this research corrected the data of all existing 24 climatic files and extended their length by 8 years, so each station now has data from 2000 to 2014. The full distribution of available weather stations (existing and new) are shown in Figure 8-1 and listed in Table 8-2.

Weather station data is stored in the 'HCD' subfolder of the 'ME Design' program folder as .hcd files. The ME software will only show the weather stations from the HCD subfolder if the station.dat file references it. The station.dat file is located in the 'Defaults' subfolder of the 'ME Design' program folder. For MDOT ME software users, the .hcd and station.dat files are all updated to reference the 39 Michigan weather stations described above.

Each station contains hourly values for the following five weather items:

- Air Temperature
- Wind Speed
- % Sunshine
- Precipitation
- % Relative Humidity

This weather data, along with the depth to water table, is used within the software in the Enhanced Integrated Climatic Model (EICM). The EICM changes the material properties of the different pavement layers based on the climatic conditions (moisture levels, temperature, etc.) throughout the year.


**Figure 8-1. Weather Stations available for ME Software**

**Table 8-2. List of Weather Stations**

| Weather Station Name | Latitude / Longitude (decimal degrees) | Location Description |
|---|---|---|
| Adrian, MI (04847) | 41.868 / -84.079 | Adrian Lenawee County Arpt |
| Alpena, MI (94849) | 45.072 / -83.581 | Alpena Co Rgnl Airport |
| Ann Arbor, MI (94889) | 42.224 / -83.74 | Ann Arbor Municipal Arpt |
| Battle Creek, MI (14815) | 42.308 / -85.251 | W K Kellogg Airport |
| Benton Harbor, MI (94871) | 42.129 / -86.422 | SW Michigan Regional Arpt |
| Detroit, MI (14822) | 42.409 / -83.01 | Detroit City Airport |
| Detroit, MI (94847) | 42.215 / -83.349 | Detroit Metro Wayne Co Apt |
| Detroit, MI (14853) | 42.237 / -83.526 | Willow Run Airport |
| Flint, MI (14826) | 42.967 / -83.749 | Bishop International Arpt |
| Gaylord, MI (04854) | 45.013 / -84.701 | Otsego County Airport |
| Grand Rapids, MI (94860) | 42.882 / -85.523 | Gerald R Ford Intl Airport |
| Hancock, MI (14858) | 47.169 / -88.506 | Houghton County Memo Arpt |
| Holland, MI (04839) | 42.746 / -86.097 | Tulip City Airport |
| Houghton Lake, MI (94814) | 44.368 / -84.691 | Roscommon County Airport |
| Iron Mountain/Kingsford, MI (94893) | 45.818 / -88.114 | Ford Airport |
| Jackson, MI (14833) | 42.26 / -84.459 | Jackson Co-Rynolds Fld Arpt |
| Kalamazoo, MI (94815) | 42.235 / -85.552 | Klmazo/Btl Creek Intl Arpt |
| Lansing, MI (14836) | 42.78 / -84.579 | Capital City Airport |
| Muskegon, MI (14840) | 43.171 / -86.237 | Muskegon County Airport |
| Pellston, MI (14841) | 45.571 / -84.796 | Pellston Rgl Airport of Emmet Co |
| Pontiac, MI (94817) | 42.665 / -83.418 | Oakland Co. Intnl Airport |
| Saginaw, MI (14845) | 43.533 / -84.08 | MBS International Airport |
| Sault Ste Marie, MI (14847) | 46.467 / -84.367 | Su Ste Mre Muni/Sasn Fl Ap |
| Traverse City, MI (14850) | 44.741 / -85.583 | Cherry Capital Airport |
| Alma, MI (AMN) | 43.322 / -84.688 | Gratiot Community Airport |
| Bad Axe, MI (BAX) | 43.78 / -82.985 | Huron County Memorial Airport |
| Caro, MI (CFS) | 43.459 / -83.445 | Tuscola Area Airport |
| Newberry, MI (ERY) | 46.311 / -85.4572 | Luce County Airport |
| Escanaba, MI (ESC) | 45.723 / -87.094 | Delta County Airport |
| Frankfort, MI (FKS) | 44.625 / -86.201 | Frankfort Dow Memorial Field Airport |
| Sturgis, MI (IRS) | 41.813 / -85.439 | Kirsch Municipal Airport |
| Manistique, MI (ISQ) | 45.975 / -86.172 | Schoolcraft County Airport |
| Ironwood, MI (IWD) | 46.527 / -90.131 | Gogebic Iron County Airport |
| Ludington, MI (LDM) | 43.962 / -86.408 | Mason County Airport |
| Mount Pleasant, MI (MOP) | 43.622 / -84.737 | Mount Pleasant Municipal Airport |
| Oscoda, MI (OSC) | 44.452 / -83.394 | Oscoda Wurtsmith Airport |
| Port Huron, MI (PHN) | 42.911 / -82.529 | Saint Clair County Intnl Airport |
| Big Rapids, MI (RQB) | 43.723 / -85.504 | Roben Hood Airport |
| Gwinn, MI (SAW) | 46.354 / -87.3954 | Sawyer International Airport |

## 8.2 – Climate Inputs

The climate inputs can be found on the project's climate tab. To get to the climate tab, double click the climate node under the project name in the Explorer pane or click the space next to the tire in the cross-section view. Both are shown in Figure 8-2.

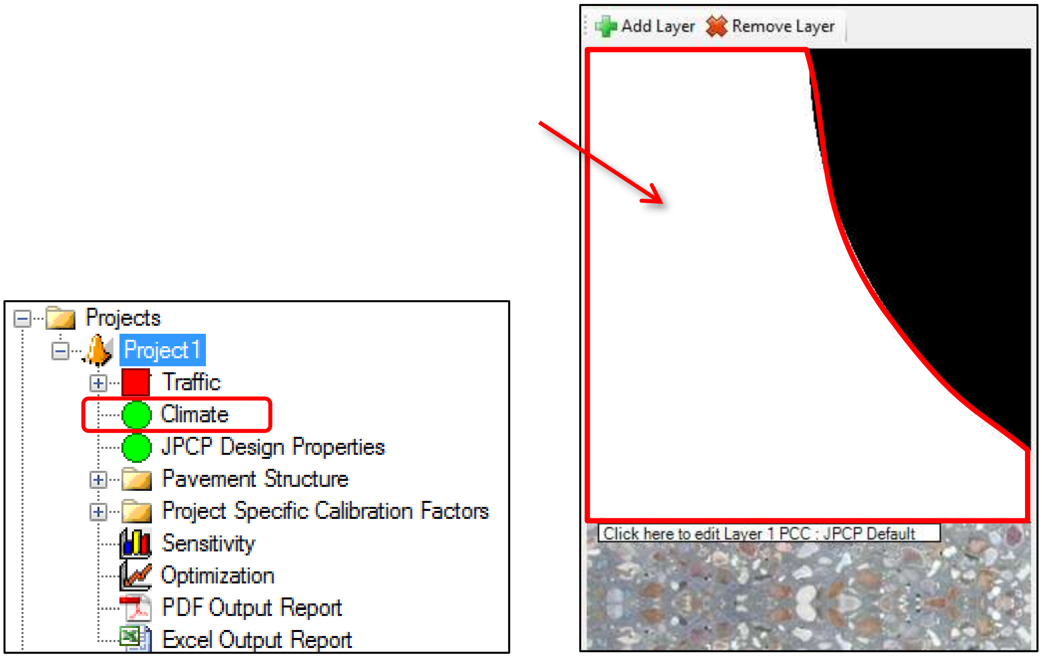



**Figure 8-2. Alternate Location for Opening Climate Tab**

The climate tab will open with the inputs on the left and the summary of the climate file on the right, as shown in Figure 8-3.

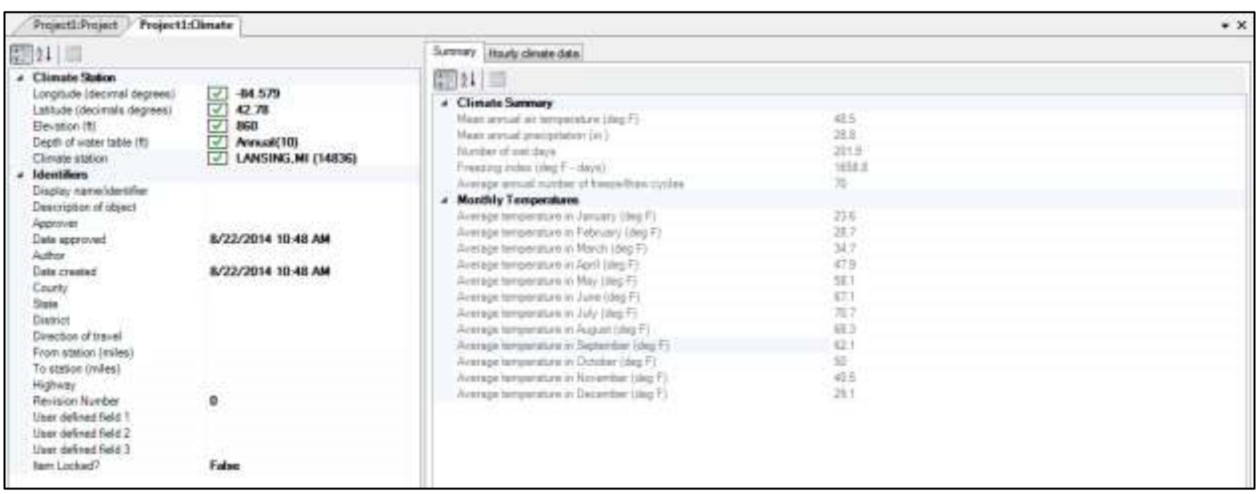
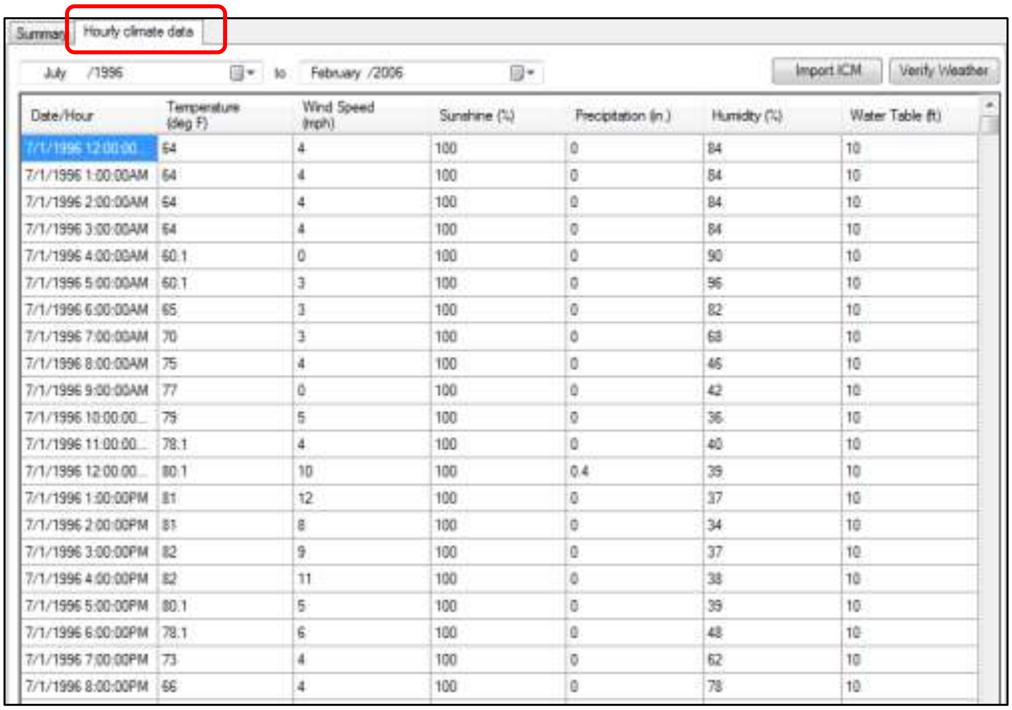



**Figure 8-3. Climate Tab**

The right side also has a second tab that shows the hourly data of the selected weather station for all 5 weather items, as shown in Figure 8-4. The months represented by the climate file can be seen at the top of the tab.




| Date/Hour | Temperature (deg F) | Wind Speed (mph) | Sunshine (%) | Precipitation (in.) | Humidity (%) | Water Table (ft) |
|---|---|---|---|---|---|---|
| 7/1/1996 12:00:00... | 64 | 4 | 100 | 0 | 84 | 10 |
| 7/1/1996 1:00:00AM | 64 | 4 | 100 | 0 | 84 | 10 |
| 7/1/1996 2:00:00AM | 64 | 4 | 100 | 0 | 84 | 10 |
| 7/1/1996 3:00:00AM | 64 | 4 | 100 | 0 | 84 | 10 |
| 7/1/1996 4:00:00AM | 60.1 | 0 | 100 | 0 | 90 | 10 |
| 7/1/1996 5:00:00AM | 60.1 | 3 | 100 | 0 | 96 | 10 |
| 7/1/1996 6:00:00AM | 65 | 3 | 100 | 0 | 82 | 10 |
| 7/1/1996 7:00:00AM | 70 | 3 | 100 | 0 | 68 | 10 |
| 7/1/1996 8:00:00AM | 75 | 4 | 100 | 0 | 46 | 10 |
| 7/1/1996 9:00:00AM | 77 | 0 | 100 | 0 | 42 | 10 |
| 7/1/1996 10:00:00... | 79 | 5 | 100 | 0 | 36 | 10 |
| 7/1/1996 11:00:00... | 78.1 | 4 | 100 | 0 | 40 | 10 |
| 7/1/1996 12:00:00... | 80.1 | 10 | 100 | 0.4 | 39 | 10 |
| 7/1/1996 1:00:00PM | 81 | 12 | 100 | 0 | 37 | 10 |
| 7/1/1996 2:00:00PM | 81 | 8 | 100 | 0 | 34 | 10 |
| 7/1/1996 3:00:00PM | 82 | 9 | 100 | 0 | 37 | 10 |
| 7/1/1996 4:00:00PM | 82 | 11 | 100 | 0 | 38 | 10 |
| 7/1/1996 5:00:00PM | 80.1 | 5 | 100 | 0 | 39 | 10 |
| 7/1/1996 6:00:00PM | 78.1 | 6 | 100 | 0 | 48 | 10 |
| 7/1/1996 7:00:00PM | 73 | 4 | 100 | 0 | 62 | 10 |
| 7/1/1996 8:00:00PM | 66 | 4 | 100 | 0 | 78 | 10 |

**Figure 8-4. Hourly Weather Data**

<u>Latitude/Longitude</u>

When choosing a single station to represent the climate for a project, the latitude and longitude of the project site does not need to be entered. However, if the information is entered, the nearest weather station will be identified automatically (see "Using latitude/longitude to select a single weather station" below). The latitude and longitude are only used by the software when creating a virtual weather station. The values will change to reflect the coordinates of the weather station chosen when using a single weather station.

<u>Elevation</u>

Similar to latitude/longitude, the elevation is only used when a virtual weather station is being created. This input is not needed since single weather stations are being used (see 'Climate Station' section below). This value will change to reflect the elevation of the weather station chosen when using a single weather station.

<u>Water Table Depth</u>

This input represents the depth to the water table from the top of the subgrade. An annual average value or seasonal water table depth can be entered. Selecting 'Seasonal' requires that the average water table depth for each of four seasons be entered. MDOT has chosen to use the annual average option. Sensitivity analysis has shown that water table depths greater than 2 feet for concrete, and 5 feet for

HMA, do not affect the distress predictions. The average annual water table depth (relative to the top of the subgrade) should be used. In the absence of this information, the designer has two choices based on any other available information (soil borings, large bodies of water nearby, low lying areas, etc.):

1. If there isn't evidence or suspicion of the water table within 5 feet of the top of subgrade, use 5 feet.
2. If there is evidence or suspicion of the water table within 5 feet (near a large body of water, low lying area, etc.), use 2 feet.

<u>Climate Station</u>

When selecting the weather station, two choices are available: use a single weather station, or create a virtual weather station. Using a single station will load all the weather data for a single station only. A virtual station is an interpolation of the weather data from several weather stations. Up to 6 single weather stations can be chosen to create a virtual station.

For MDOT projects, it was decided that using the closest single weather station is sufficient. To do this, use the following steps and as shown in Figure 8-5:

<u>Selecting a Single Weather Station</u>

- Click the box containing the station name to obtain the drop-down arrow, and then select the drop-down arrow.
- Select the 'Use Single Weather Station' radio button.
- Make sure that 'MI' is selected in the 'State/Province' drop-down box.
- Choose the correct station from the drop-down list (the latitude, longitude, and elevation will automatically change to those of the weather station – this is fine since a single weather station is being used).
    - Note that there are three Detroit weather stations listed – see the list below to determine the correct one.
        - Detroit (14822) = Detroit City Airport (now known as Coleman A. Young Airport)
        - Detroit (94847) = Detroit Metro Airport
        - Detroit (14853) = Willow Run Airport
- Click outside the climate station box to complete the selection.

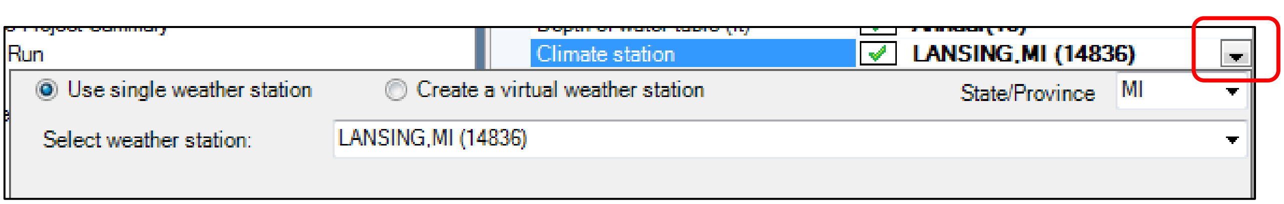



**Figure 8-5. Single Climate Station Input Box**

If it is not clear which weather station is closest to the project site, the latitude and longitude can be used to determine this.  To do this, follow these steps and as shown in Figure 8-6:

Using latitude/longitude to select a single weather station

- Enter a latitude and longitude (in decimal format) that represents the center of the project location.
- Click the box containing the station name to obtain the drop-down arrow, and then select the drop-down arrow.
- Select the ‘Create A Virtual Weather Station’ radio button.
- A list of nearby weather stations will be listed in order of shortest distance to the latitude and longitude entered.
- Note the closest station.  There are three Detroit stations, so the airport listed in the ‘Description’ column will also need to be noted.
- Follow the instructions above (per ‘Selecting a Single Weather Station’) for entering a single weather station.

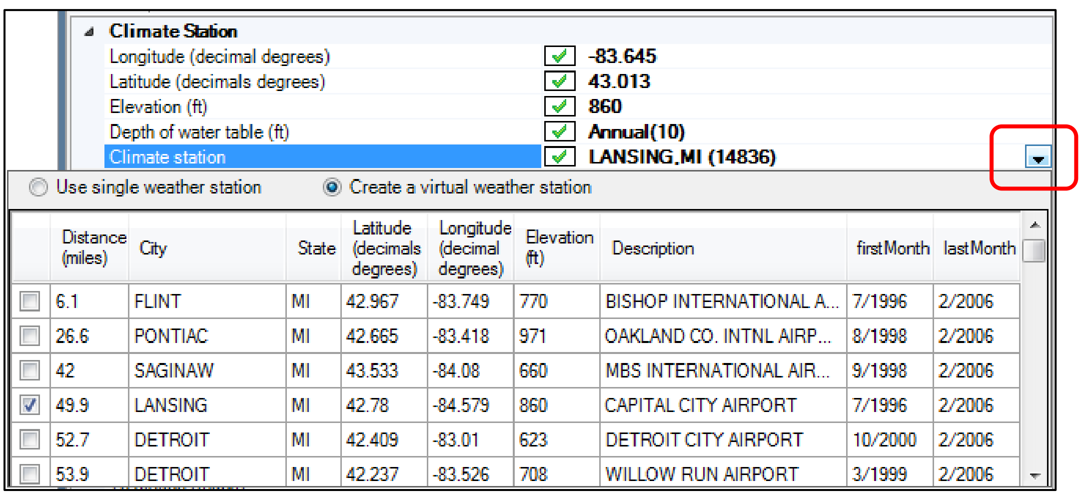



**Figure 8-6.  Virtual Climate Station Input Box**

# Chapter 9 – Asphalt Pavement (New) Layer Inputs

**Table 9-1. Recommended Asphalt Pavement (New) Property Inputs (Used for All New HMA Layers)**

| Input | | | Units | Recommended Value |
|---|---|---|---|---|
| AC Layer Properties | Uses multi-layer rutting calibration | | | False *(software default)* |
| | AC Surface Shortwave Absorptivity | | | 0.85 *(software default)* |
| | Is endurance limit applied? | | | False *(software default)* |
| | Endurance limit | | Microstrain | 125 |
| | Layer Interface | Interface Friction | | 1 (for all interfaces) *(software default)* |

***Bold** = sensitive input

**Table 9-2. Recommended Asphalt Pavement (New) Layer Related Inputs**

| Input | | | Units | Recommended Value |
|---|---|---|---|---|
| Asphalt Layer | **Thickness** | | **inches** | **Variable per project and layer** |
| Mixture Volumetrics | Unit weight | | $lbs/ft^3$ | Typical of designated mix (see Section 9.4.2 – Mixture Volumetrics) |
| | **Effective binder content** | | **%** | **Typical of designated mix** (see Section 9.4.2 – Mixture Volumetrics) |
| | **Air voids** | | **%** | **Typical of designated mix** (see Section 9.4.2 – Mixture Volumetrics) |
| | **Poisson's ratio** | **Poisson's ratio calculated?** | | **False *(software default)*** |
| | | **Poisson's ratio** | | **0.35 *(software default)*** |
| | | **Poisson's ratio parameter A** | | **N/A *(software default)*** |
| | | **Poisson's ratio parameter B** | | **N/A *(software default)*** |
| Mechanical Properties | **Dynamic modulus input level – Level 1** | **Dynamic modulus input level** | | **SELECT** |
| | | **Temperature levels** | **°F** | **Test/predicted values for mix/binder being used at each temperature level (typ.): 14, 40, 70, 100, 130 °F** |
| | | **Frequency levels** | **hertz** | **Test/predicted values for mix/binder being used at each frequency level (typ.): 0.1, 1, 10, 25 Hz** |
| | **Dynamic modulus input level – Level 2** | **Dynamic modulus input level** | | **DO NOT SELECT** |
| | | **Gradation** | | **N/A** |
| | **Dynamic modulus input level – Level 3** | **Dynamic modulus input level** | | **DO NOT SELECT** |
| | | **Gradation** | | **N/A** |
| | Select HMA Estar predictive model | Using G* based model (not nationally calibrated) | | False *(software default)* |
| | Reference temperature | | °F | 70 *(software default)* |

| Input | | | | | Units | Recommended Value |
|---|---|---|---|---|---|---|
| | Asphalt binder – Level 1<br>*NOTE: Auto-selected when Dynamic modulus is Level 1* | Superpave Performance Grade | Superpave Performance Grade | | | SELECT |
| | | | Temperature | | °F | Each temperature tested; Typically 40, 70, 100, 130, 168 degrees F. |
| | | | Binder G* | | Pascals | Test results at each temperature for binder being used. |
| | | | Phase angle | | ° | Test results at each temperature for binder being used. |
| | | Penetration/ Viscosity Grade | Penetration/Viscosity Grade | | | DO NOT SELECT |
| | | | Softening point at 13000 Poise | | °F | N/A |
| | | | Absolute viscosity at 140°F | | Poise | N/A |
| | | | Kinematic viscosity at 275°F | | centistokes | N/A |
| | | | Specific gravity at 77°F | | | N/A |
| | | | Penetration | Temp. | °F | N/A |
| | | | | Penetr. | | N/A |
| | | | Brookfield Viscosity | Temp. | °F | N/A |
| | | | | Brookf. Visc. | centipoise | N/A |
| | Asphalt binder – Level 2<br>*NOTE: This is not an available option* | | | | | N/A |
| | Asphalt binder – Level 3<br>*NOTE: Auto-selected when Dynamic modulus is Level 2 or 3, which are not used.* | Superpave performance grade | | Binder type | | N/A |
| | | Viscosity grade | | Binder type | | N/A |
| | | Penetration grade | | Binder type | | N/A |
| | Indirect tensile strength at 14°F | | | | psi | Enter test/predicted values for mix/binder being used. |
| | Creep compliance – Level 1<br>*First choice* | Creep compliance level | | | psi | SELECT (when mix has test/predicted values) |
| | | Low temperature | | | psi | Enter values for mix/binder being used |
| | | Mid temperature | | | psi | Enter values for mix/binder being used |
| | | High temperature | | | psi | Enter values for mix/binder being used |

| Input | | | Units | Recommended Value |
|---|---|---|---|---|
| | **Creep compliance – Level 2** | **Creep compliance level** | | **DO NOT SELECT** |
| | | **Mid temperature** | **psi** | **N/A** |
| | **Creep compliance – Level 3** | **Creep compliance level** | | **DO NOT SELECT** |
| Thermal | Thermal conductivity | | BTU/hr-ft-°F | 0.67 *(software default)* |
| | **Heat capacity** | | **BTU/lb-°F** | **0.23 *(software default)*** |
| | Thermal contraction | Is thermal contraction calculated? | | True *(software default)* |
| | | Mix coefficient of thermal contraction | in./in./°F | N/A *(software default)* |
| | | Aggregate coefficient of thermal contraction | in./in./°F | 5E-06 *(software default)* |
| | | Voids in Mineral Aggregate | % | N/A *(software default)* |

***Bold** = sensitive input

### 9.1 – Introduction

Chapter 9 applies to the inputs and properties of new asphalt pavement layers, which include Hot Mix Asphalt (HMA), Warm Mix Asphalt (WMA), and Asphalt Stabilized Crack Relief Layers (ASCRL). The ME software allows up to three Asphalt Layers for new flexible pavement designs. Inputs for existing asphalt layers can be found in Chapter 13 – Existing Layer Inputs for Rehabilitation Design.

The Asphalt Layer is defined by its aggregate mixture and binder characteristics. These are determined by traffic, climate, location, and other unique design features. Aggregate mixture and binder selection are outlined in Section 9.2 – Asphalt Mix and Binder Selection.

In the ME software, begin a new asphalt pavement design by selecting "New Pavement" for 'Design Type' and "Flexible Pavement" for 'Pavement Type' in the General Information area of the main Project tab (see Chapter 4 – General Inputs). After this step, an initial Asphalt Layer will appear in the main Project tab. Asphalt related inputs are located in the Asphalt Layer tab(s) and AC Layer Properties tab within the main Project tab or by selecting the project folder of the Explorer menu. In the Explorer menu, view the Asphalt Layer tab(s) by expanding the Pavement Structure folder drop-down node.

The AC Layer Properties tab defines common design features used for all added Asphalt Layers. Each added Asphalt Layer is defined within its own tab of the Pavement Structure. AC Layer Properties tab inputs are outlined in Section 9.3 – AC Layer Properties Tab Inputs and Asphalt Layer inputs are outlined in Section 9.4 – Asphalt Layer Tab Inputs.

## 9.2 – Asphalt Mix and Binder Selection

Section 6.03.09 of the MDOT *Road Design Manual* specifies the guidelines for MDOT HMA mixture and binder selection. To establish the ESAL values used for mix selection, see Section 7.2 – Obtaining Traffic Inputs (Traffic Request Procedure). To establish the preliminary thicknesses used for mix selection, create the initial design using *AASHTO's Guide For Design of Pavement Structures, 1993* (see Section 3.1.3 – Step 3: Create Initial Trial Design) and standards for MDOT pavement design in APPENDIX A – DARWin Inputs (AASHTO 1993 Method). Note that the asphalt mixtures and thicknesses may require changes based on ME design and analysis.

Asphalt mixtures and binders were tested for mechanical properties (see Section 9.4.3 – Mechanical Properties), which include 'Dynamic modulus' (|E*|) of the mix, complex shear modulus (|G*|) of the binder, 'Creep compliance' (D(t)) of the mix, and 'Indirect tensile strength' (IDT) of the mix. To convert the asphalt mixture and binder test results into acceptable ME software requirements, an external application, DynaMOD was developed as part of the Michigan State University 2012 study RC-1593. DynaMOD was developed to serve as a database for all HMA material testing and to generate input files from the test results that can be imported into the ME software. Note that not all generated input files are directly importable, and instead must be copied and pasted into the ME software. DynaMOD also incorporates predictive models to create outputs for mixes or binders that have not been tested. The two predictive models for |E*| are the Modified Witczak and Artificial Neural Network (ANN) models. The ANN model, in general, is more accurate than the locally calibrated Modified Witczak model. Therefore, the ANN model is primarily used for |E*| prediction. Using similar modeling techniques, D(t) and IDT may also be predicted as needed. There are no predictive equations for the |G*| in DynaMOD. The input files generated from DynaMOD are stored in a designated folder location for use by MDOT designers. This location is identified in Section 3.1.8 – Step 8: Add/Delete Layers; Change Material Inputs. The Pavement Management Section is responsible for DynaMOD operation and provides the input files for the ME software.

Note that pre-made HMA layers for common mix types and binder by region are available for import to quickly add new HMA layers. Before utilizing the separate input files for |E*|, |G*|, D(t), and IDT, see if an HMA layer is available for import in the folder identified in Section 3.1.8 – Step 8: Add/Delete Layers; Change Material Inputs. If so, import this layer in Pavement ME by opening the Pavement Structure folder and right-clicking an existing HMA layer tab in the Explorer menu. An option list will appear. Select the option 'Import'. Based on the HMA layer region and type, use the designated import folder location to locate the appropriate XML file. After opening this file, the layer inputs will be populated with the associated data.

For the ME inputs |E*|, |G*|, D(t), and IDT, utilize the test result input file that matches the selected layer mixture and binder. However, if the associated test result input file is not available, select an alternative file as shown in order of preference (and note in 'User defined field' what method was used):

1. Use a predicted input file (files are identified by the use of 'predicted' in the filename).
2. Use a test/predicted input file from the same region, with the same mix, but a different binder (no more than one grade change on the high or low temperature sides)
3. Use a test/predicted input file from the same region, with the same binder, but a different mix number having the same traffic level (i.e., 4E3 mix test results in place of a 5E3, 3E30 mix test results in place of a 2E30, etc.). Mix numbers allowed by the HMA Mixture Selection Guidelines for each of the HMA courses must still be followed (i.e., 5 mix test results cannot be used for a base course, 3 mix test results cannot be used for a top course, etc.).
4. Use ESAL value to select the test/predicted input file of the closest traffic level (i.e. 3E50 to 3E30).

Note that options 2, 3, and 4 utilize test results from a different mix and/or binder from what is specified for the design. In these instances, **do <u>not</u>** change the design specified mix and/or binder to those of the alternative test/predicted result being used. Instead, note what test/predicted results were used in 'User defined field 2' or 'User defined field 3' under the 'Identifiers' section of the layer inputs area (see Figure 9-1 below).

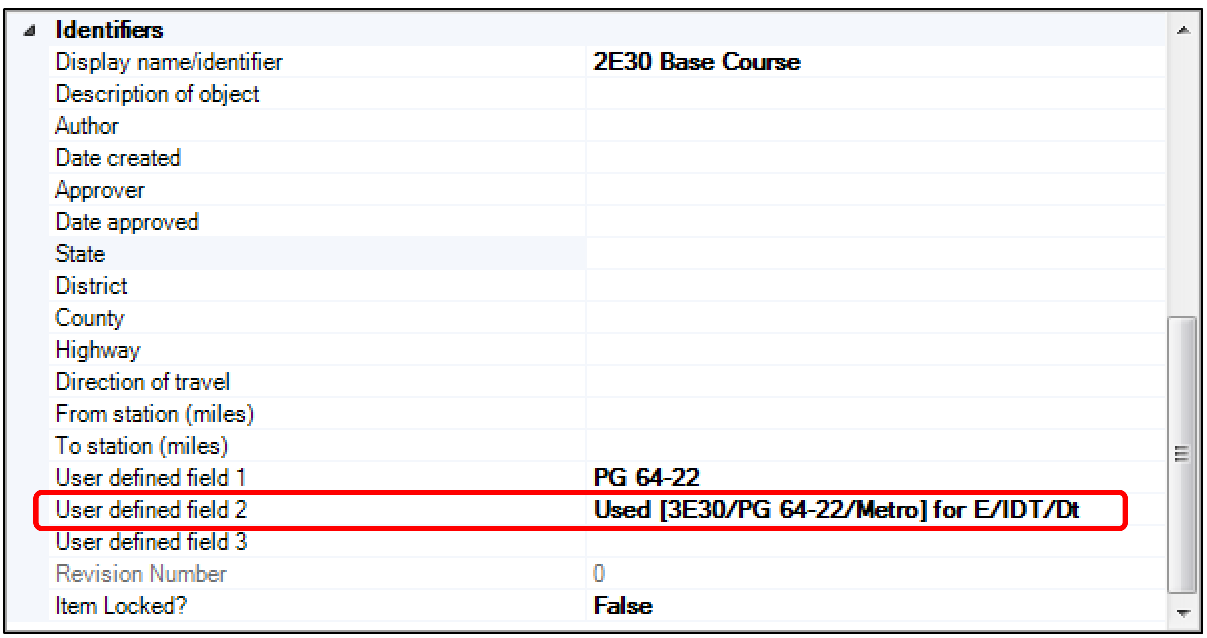



**Figure 9-1. Alternative Test/Predicted File Notation Example**

### 9.3 – AC Layer Properties Tab Inputs

Common inputs and properties used for all new Asphalt Layers are accessed by selecting the AC Layer Properties tab under the project folder of the Explorer menu. This area can also be accessed by selecting the Property Control drop-down menu of the main Project tab.

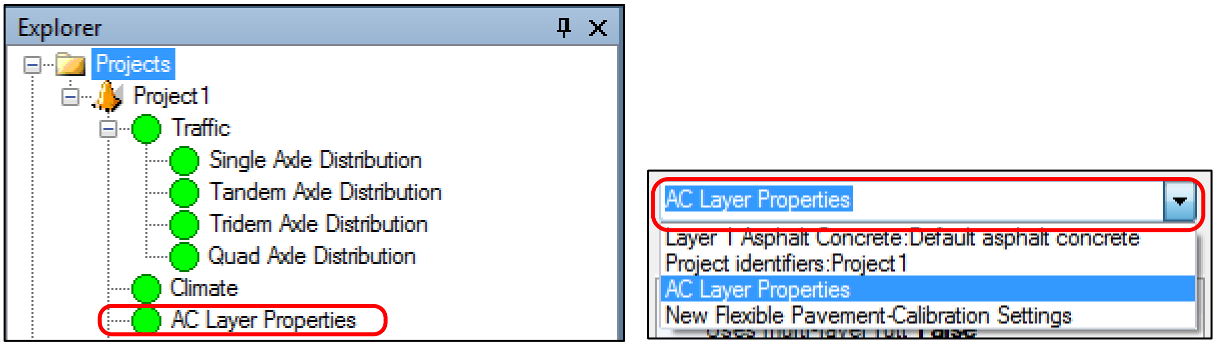



**Figure 9-2. AC Layer Properties Tab Access Locations**

AC Layer Properties tab areas (drop-down heading):

- AC Layer Properties

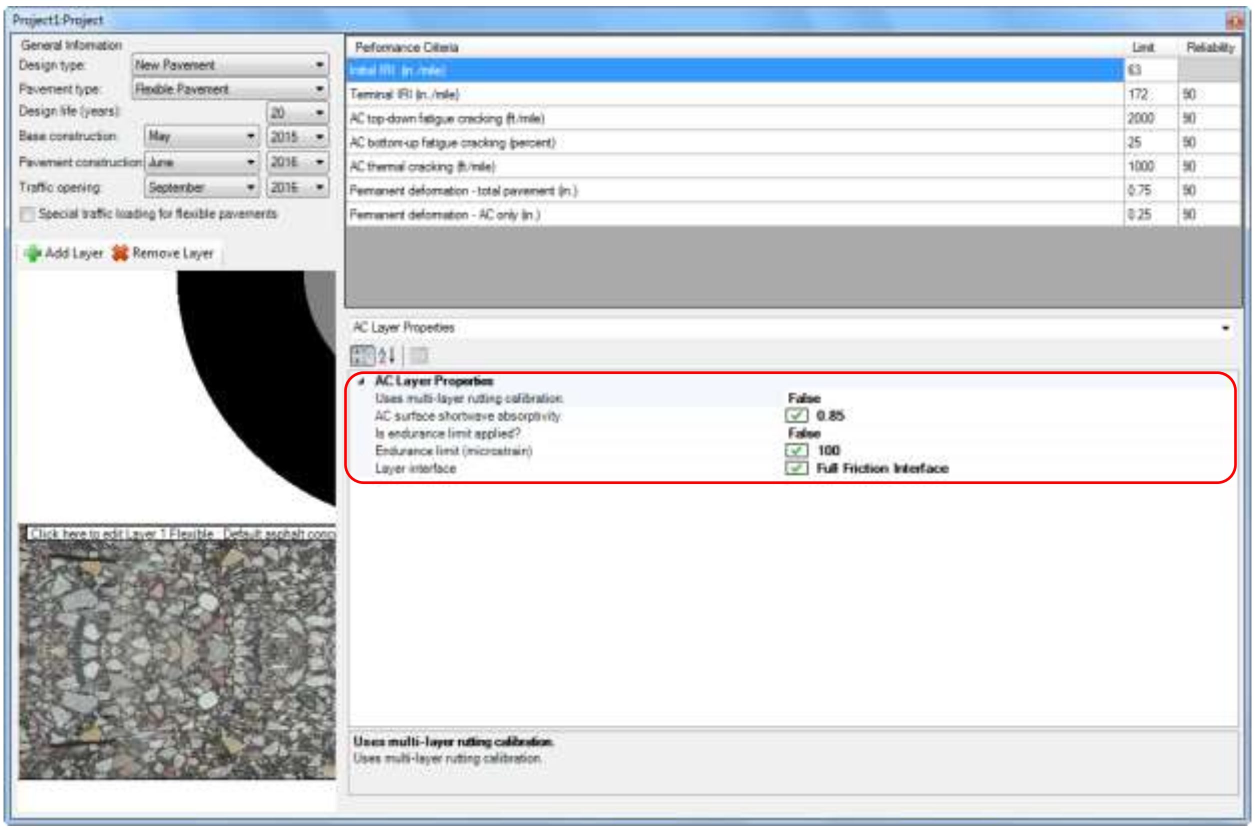



**Figure 9-3. AC Layer Properties Tab Area**

### 9.3.1 – AC Layer Properties

<u>Uses multi-layer rutting calibration</u>

This input identifies how the rutting calibration factors will be applied to the asphalt pavement section and its new Asphalt Layers. Use the default selection "False." This option applies one set of rutting calibration factors for all added Asphalt Layers. Selecting "True" will use different sets of calibration factors for each Asphalt Layer. If "True" is selected, up to three sets of rutting calibration factors can be used.

Calibration was conducted using one set of rutting calibration factors (“False” selection). This option was added to the software shortly before calibration was completed, so it was not explored.

<u>AC Surface Shortwave Absorptivity</u>
Enter the fraction of available solar energy absorbed by the asphalt pavement surface. AASHTO recommends using the ME software default value of 0.85. Use this value.

<u>Is endurance limit applied?</u>
This input identifies whether the entered ‘Endurance Limit’ (see below) will be used in the design analysis. Use the default selection, “False.” Selecting “True” will have the ME software use the entered ‘Endurance Limit’ in the design analysis and selecting “False” will not.

If “True” is selected, each time the ME software calculates strain at the bottom of the Asphalt Layer, it will check that strain value against the value entered for ‘Endurance Limit’. If the calculated strain is below the ‘Endurance Limit’, then it will not accumulate ‘AC bottom-up fatigue cracking’ damage for that truck load.

Using an entered ‘Endurance Limit’ may be appropriate for HMA perpetual pavement designs, but a research project would be needed to further explore this and determine an appropriate value. At this time, perpetual pavement designs are not part of the Department’s standard fix types.

<u>Endurance limit</u>
This input identifies the tensile strain below which no fatigue damage occurs, also known as the Endurance Limit, in microstrain. While this input will not be utilized, as identified in ‘Is endurance limit applied?’ (see above), input 125 microstrain as a placeholder.

<u>Layer Interface</u>
This option opens a table where the bond between adjacent layers can be identified. The ME software allows a different value to be entered for each interface. Only the layers that are currently added will appear in the table. A value between 0 and 1 may be entered for each layer to indicate how much it is expected to bond to the layer below. 0 is a full-slip condition, and 1 is a full-bond condition. No value is entered for the bottom layer because it is assumed to be semi-infinite. National experts strongly recommend using 1 for all layers to identify full-bond conditions. Use the ME software default value of 1 for all interfaces.

### 9.4 – Asphalt (New) Layer Tab Inputs

Asphalt (New) Layer inputs can be accessed by selecting an Asphalt Layer tab under the Pavement Structure folder of the project folder in the Explorer menu, by selecting the Property Control drop-down menu of the main Project tab, or by selecting the layer shown in the Pavement Structure display area of the main Project tab.

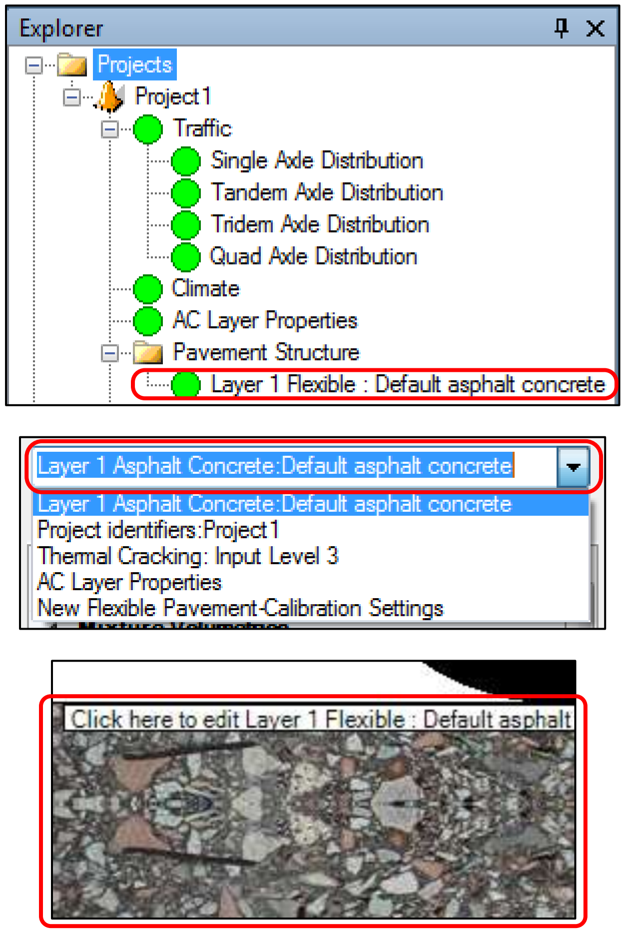



**Figure 9-4. Asphalt (New) Layer Tab Access Locations**

Asphalt (New) Layer tab areas (drop-down headings):

- Asphalt Layer
- Mixture Volumetrics
- Mechanical Properties
- Thermal
- Identifiers

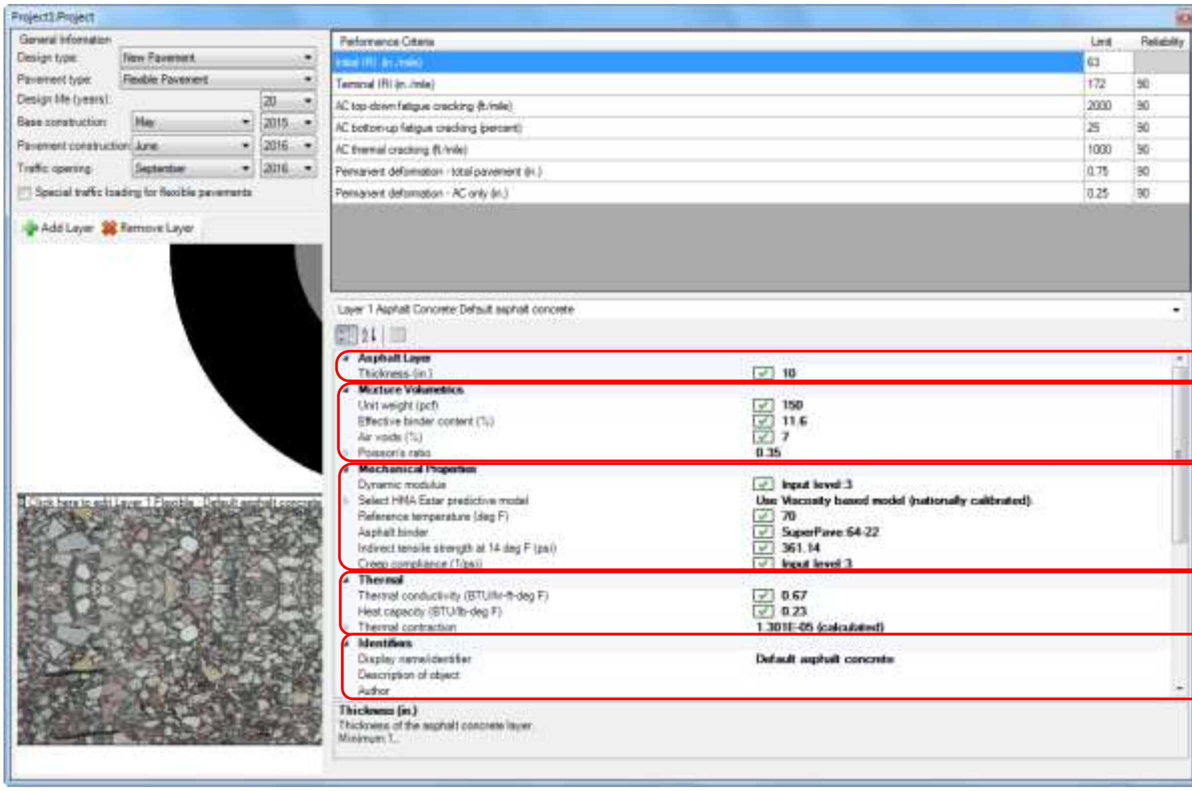



**Figure 9-5. Asphalt (New) Layer Tab Areas (Headings)**

### 9.4.1 – Asphalt Layer

<u>Thickness</u>

Enter the thickness, in inches, of the selected layer. The distress outputs are sensitive to this input. This input should be identified by the designer, following MDOT standards per mix type as outlined in Section 6.03.09 of the MDOT *Road Design Manual*.

### 9.4.2 – Mixture Volumetrics

<u>Unit weight (pcf)</u>

Enter the unit weight of the mix in pounds per cubic foot. This value is typical of the designated mix as shown in the table below:

**Table 9-3. Unit Weight per Asphalt Mixture Number**

| | Unit Weight (pcf) |
|---|---|
| **5 mix** | 145.2 |
| **4 mix** | 146.4 |
| **3 mix** | 147.6 |
| **2 mix** | 151.6 |
| **Gap Graded Superpave (GGSP)** | 147.9 |
| **Low Volume Superpave (LVSP)** | 145.3 |

Information from 2017 project test results were compiled and averaged to obtain unit weights of each Asphalt Layer type. Asphalt mix selection is outlined in Section 9.2 – Asphalt Mix and Binder Selection.

Effective binder content (%)

Enter the volume of the effective binder as a percentage of the overall volume of the mix. This value is typical of the designated mix as shown in the table below:

**Table 9-4. Effective Binder Content per Asphalt Mixture Number**

| | Effective Binder Content (%) |
|---|---|
| **5 mix** | 12.6 |
| **4 mix** | 11.5 |
| **3 mix** | 10.8 |
| **2 mix** | 9.7 |
| **GGSP** | 14.0 |
| **LVSP** | 11.6 |

Information from 2017 project test results were compiled and averaged to obtain effective binder contents of each Asphalt Layer type. Asphalt mix selection is outlined in Section 9.2 – Asphalt Mix and Binder Selection. The distress outputs are sensitive to this input.

Air Voids (%)

Enter the volume of the air voids after construction as a percentage of the overall volume of the mix. This value is typical of the designated mix as shown in the table below:

**Table 9-5. Air Voids per Asphalt Mixture Number**

| | Air Voids (%) |
|---|---|
| **5 mix** | 6.0 |
| **4 mix** | 6.1 |
| **3 mix** | 5.8 |
| **2 mix** | 4.8 |
| **GGSP** | 7.3 |
| **LVSP** | 5.6 |

Information from 2017 project test results were compiled and averaged to obtain air voids of each Asphalt Layer type. Asphalt mix selection is outlined in Section 9.2 – Asphalt Mix and Binder Selection. The distress outputs are sensitive to this input.

Poisson's ratio

This input allows the user to enter the Poisson's ratio of the mix as a function of 'Dynamic modulus' (see Section 9.4.3 – Mechanical Properties), or as a constant value. Poisson's ratio is the ratio of perpendicular strain to axial strain when the material is placed under load. Use the default option and value for a constant Poisson's ratio ("False" selection) at a value of 0.35.

The ME software default option is “False” for calculate, which means that it will use a constant value for Poisson’s Ratio. Use the default option and leave the calculate option as “False”. Using this option allows the user to define a constant value of Poisson’s ratio below, (which is disabled if “True” is selected). The default value is 0.35. Use the default value.

By selecting “True” to calculate, the software will calculate Poisson’s Ratio as a function of ‘Dynamic modulus’. This option allows the user to specify Parameters A and B of the Poisson’s ratio model, (which are disabled is “False” is selected). The default values of Parameters A and B are -1.63 and 3.84E-06, respectively.

### 9.4.3 – Mechanical Properties

Dynamic modulus

This input allows the user to enter the dynamic modulus of the mix from test or predicted test results, or as calculated by the ME software based on binder inputs and aggregate gradations of the mix. The Level 1 selection allows the user to enter test or predicted test results, and Levels 2 and 3 allow the user to enter aggregate gradations. Select the Level 1 option and input the test or predicted results at each testing temperature and frequency. Do not select the Level 2 or 3 options. The distress outputs are sensitive to this input.

For ‘Dynamic modulus input level’, select Level 1. Based on the identified asphalt mix and binder (see Section 9.2 – Asphalt Mix and Binder Selection), use the designated folder location (identified in Chapter 3 – Design Process) to locate the appropriate excel file. Copy the contents of the table from the excel file and paste this information into the ME software dynamic modulus table. If for any reason the necessary excel file is not available, contact the Pavement Management Section for guidance.

The temperature and frequency levels should be left as defaults. All testing and predicted values are associated to these levels.

Select HMA Estar predictive model

This input identifies which model is used to predict the ‘Dynamic modulus’ (see above) values, also known as E*. Use the default selection, “False”. Selecting “True” will use the G* based model that adjusts viscosity by frequency to determine the ‘Dynamic modulus’. Selecting “False” will not adjust viscosity by frequency.

The G* based model (“True” selection) is not necessary since the ‘Dynamic modulus’ will be entered using actual values. The G* based model has not been nationally calibrated.

Reference temperature (deg F)

Enter the baseline temperature, in degrees Fahrenheit, used as the reference for the ‘Dynamic modulus’ (see above) testing. This is a typical value of 70°F, which is suggested by AASHTO. Use the ME software default value of 70°F.

Asphalt binder

This input allows the user to define the asphalt binder properties of the Asphalt Layer mix. The options within its drop-down menu vary depending on the ‘Dynamic modulus’ (see above) input level that is selected. When Levels 1 or 2 are selected for ‘Dynamic modulus’, this input automatically uses Level 1 input options. When Level 3 is selected for ‘Dynamic modulus’, this input automatically uses Level 3 input options. Since Level 1 ‘Dynamic modulus’ will be used, this input will use Level 1 options. This requires lab tested values. The distress outputs are sensitive to this input.

For the Level 1 input, there will be two options, ‘Superpave Performance Grade’ and ‘Penetration/Viscosity Grade’. Since MDOT does not use penetration or viscosity graded binders and instead uses Superpave performance graded binders, select ‘Superpave Performance Grade’. The test data from the asphalt binders are entered in the table below (see Section 9.2 – Asphalt Mix and Binder Selection). Test results should identify the test temperatures, resultant dynamic shear modulus (|G*|), and the resultant phase angle (which identifies whether the binder is behaving viscous or elastic at the temperature being tested). To add the appropriate test information to the table, right-click anywhere in the table. An option list will appear. Select the option “Import MEPDG Binder (.bif) format”. Based on the identified asphalt binder (see Section 9.2 – Asphalt Mix and Binder Selection), use the designated folder location (identified in Chapter 3 – Design Process) to locate the appropriate BIF file. After opening this file, the table will be populated with the associated test data. If for any reason the necessary BIF file is not available, contact the Pavement Management Section for guidance.

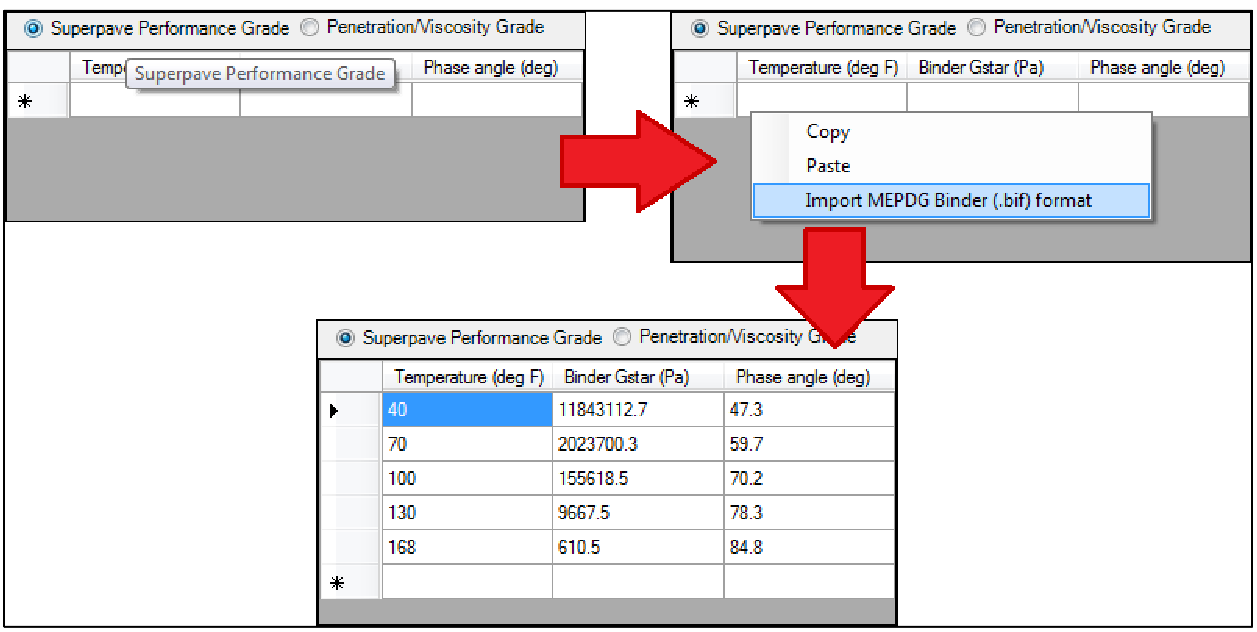



**Figure 9-6. Asphalt Binder Table Operation**

Indirect tensile strength at 14 deg F (psi)
Enter the indirect tensile (IDT) strength of the asphalt mixture at a temperature of 14˚F. This is the measure of the thermal cracking susceptibility of the mix. The ME software internally calculates this value based on other inputs, but can be overridden with a test result value. Use the appropriate test result value, if available. The distress outputs are sensitive to this input.

Based on the identified asphalt mix and binder (see Section 9.2 – Asphalt Mix and Binder Selection), use the designated folder location (identified in Chapter 3 – Design Process) to locate the appropriate excel file. Copy the 'Average IDT Strength' from the excel file and paste this information into the ME software. If the necessary excel file is not available, allow the ME software to calculate the input by not making any changes.

Creep compliance (1/psi)
This input allows the user to enter the creep compliance (D(t)) of the mix from test or predicted test results, or as calculated by the ME software based on statistical relationships with other inputs. Creep compliance is the time-dependent strain per unit stress of the asphalt mixture. Selecting Level 1 allows the user to enter test or predicted test results at required temperatures -4, 14 and 32˚F per loading time (1, 2, 5, 10, 20, 50, and 100 seconds). Selecting Level 2 allows the user to enter test or predicted test results only at 14˚F per loading time. Selecting Level 3 allows the ME software to automatically calculate the mix creep compliance. Select the Level 1 option and input the test or predicted results at each required testing temperature. If the appropriate mix is not available, select Level 3. Do not select the Level 2 option. The distress outputs are sensitive to this input.

For 'Creep compliance level', select Level 1. Based on the identified asphalt mix and binder (see Section 9.2 – Asphalt Mix and Binder Selection), use the designated folder location (identified in Chapter 3 – Design Process) to locate the appropriate excel file. Copy the data from the 'D(t)' table in the excel file and paste this information into the ME software.

### 9.4.4 – Thermal

Thermal conductivity (BTU/hr-ft-deg F)
Enter the thermal conductivity of the Asphalt Layer. Thermal conductivity is the measure of a material's propensity to conduct heat. Typical values for thermal conductivity of HMA range from 0.44 to 0.81. Use the ME software default value of 0.67 BTU/hr-ft-°F.

Heat capacity (BTU/lb-deg F)
Enter the heat capacity of the Asphalt Layer. Heat capacity is the amount of heat in BTU needed to increase the temperature of one pound of the material by one-degree Fahrenheit. Typical values for heat capacity of HMA range from 0.22 to 0.40. Use the ME software default value of 0.23 BTU/lb-°F.

Thermal contraction

This input allows the user to enter the thermal contraction of the mix from test results, or as calculated by the ME software as a function of the aggregates. Thermal contraction is the measure of a material's tendency to change in volume due to change in temperature. Currently, there are no standard tests for this input. Use the ME software default selection of "True" and allow the software to internally calculate the thermal contraction. This input includes the following options:

- Is thermal contraction calculated?
  - Selecting "True" allows the ME software to automatically calculate the thermal contraction as a function of the aggregates using the values in 'Aggregate coefficient of thermal contraction' and 'Voids in Mineral Aggregate' (see below). This is the default selection and should be used.
  - Selecting "False" allows the user to manually enter the mix thermal contraction in 'Mix coefficient of thermal contraction' (see below). Do not make this selection.
- Mix coefficient of thermal contraction: If "False" is selected for the first option above, enter the mix test results for coefficient of thermal contraction. The ME software default value is 1.3E-05 in./in./˚F.
- Aggregate coefficient of thermal contraction: If "True" is selected for the first option above, enter the coefficient of thermal contraction of the aggregates. Use the ME software default value of 5.0 E-06 in./in./˚F.
- Voids in Mineral Aggregate: If "True" is selected for the first option above, this input is automatically calculated by the ME software as the percent volume of voids in the mineral aggregate. This value equals percent volume of air voids plus percent volume of asphalt binder minus percent volume of absorbed asphalt binder.

## Chapter 10 – Concrete Pavement (New) Layer Inputs

**Table 10-1. Recommended Jointed Plain Concrete Pavement (New) Property Inputs**

| Input | | | Units | Recommended Value |
|---|---|---|---|---|
| JPCP Design | **PCC surface shortwave absorptivity** | | | **0.85 *(software default)*** |
| | **PCC joint spacing** | **Is joint spacing random?** | | **False *(software default)*** |
| | | **Joint spacing** | **feet** | **Based on JPCP Thickness per MDOT Standard Plan R-43** |
| | | **Spacing of Joint 1** | **feet** | **N/A** |
| | | **Spacing of Joint 2** | **feet** | **N/A** |
| | | **Spacing of Joint 3** | **feet** | **N/A** |
| | | **Spacing of Joint 4** | **feet** | **N/A** |
| | Sealant type | | | Other |
| | **Doweled joints** | **Is joint doweled?** | | **True *(software default)*** |
| | | **Dowel diameter** | **inches** | **Based on JPCP Thickness per MDOT Standard Plan R-41** |
| | | **Dowel spacing** | **inches** | **12 *(software default)*** |
| | **Widened slab** | **Is slab widened?** | | **False *(software default)*** |
| | | **Slab width** | **feet** | **N/A *(software default)*** |
| | **Tied shoulders** | **Tied shoulders** | | **Per Shoulder Type:**<br>• **Concrete (incl. C&G): True**<br>• **Asphalt: False *(software default)*** |
| | | **Load transfer efficiency** | **%** | **Per 'Tied shoulders':**<br>• **If True: 50 *(software default)***<br>• **If False: N/A *(software default)*** |
| | Erodibility index | | | Per Base Layer type:<br>• Unbound: 4<br>• Stabilized: 1 |
| | PCC-base contact friction | PCC-Base full friction contact | | True *(software default)* |
| | | Months until friction loss | months | 60 |
| | **Permanent curl/warp effective temperature difference** | | **°F** | **-10 *(software default)*** |

***Bold** = sensitive input

**Table 10-2. Recommended Jointed Plain Concrete Pavement (New) Layer Related Inputs**

| Input | | | Units | Recommended Value |
|---|---|---|---|---|
| PCC | **Thickness** | | **inches** | **Variable per project** |
| | Unit Weight | | lbs/ft$^3$ | 145 |
| | Poisson's ratio | | | 0.2 *(software default)* |
| Thermal | **PCC coefficient of thermal expansion** | | **(in./in./°F) x (10$^{-6}$)** | **Per region:**<br>• **BAY, GRD, NOR, SW, SUP: 4.4**<br>• **MET, UNIV: 5.0** |
| | **PCC thermal conductivity** | | **BTU/hr-ft-°F** | **1.25 *(software default)*** |
| | PCC heat capacity | | BTU/lb-°F | 0.28 *(software default)* |
| Mix | Cement type | | | Type I (1) *(software default)* |
| | Cementitious material content | | lbs/yd$^3$ | 500 |
| | Water to cement ratio | | | 0.42 *(software default)* |
| | Aggregate type | | | Limestone |
| | **PCC zero-stress temperature** | **Calculated internally?** | | **True *(software default)*** |
| | | **User-specified PCC set temperature** | **°F** | **N/A** |
| | Ultimate shrinkage | Calculated internally? | | True *(software default)* |
| | | User-specified PCC ultimate shrinkage | microstrain | N/A |
| | Reversible shrinkage | | % | 50 *(software default)* |
| | Time to develop 50% of ultimate shrinkage | | days | 35 *(software default)* |
| | Curing method | | | Curing Compound *(software default)* |
| Strength | **PCC strength and modulus – Level 1** | **PCC strength input level** | | **DO NOT SELECT** |
| | | **Modulus of rupture** | **psi** | **N/A** |
| | | **Elastic modulus** | **psi** | **N/A** |
| | **PCC strength and modulus – Level 2** | **PCC strength input level** | | **DO NOT SELECT** |
| | | **Compressive strength** | **psi** | **N/A** |
| | **PCC strength and modulus – Level 3** | **PCC strength input level** | | **SELECT** |
| | | **28-Day PCC modulus of rupture** | **psi** | **N/A** |
| | | **28-Day PCC compressive strength** | **psi** | **5600** |
| | | **28-Day PCC elastic modulus** | **psi** | **Uncheck box (empty box)** |

***Bold** = sensitive input

## 10.1 – Introduction

Chapter 10 applies to the inputs and properties of new concrete pavements (PCC), which include Jointed Plain Concrete Pavements (JPCP) and Continuously Reinforced Concrete Pavements (CRCP). However, only JPCP designs will be fully covered by this chapter. Currently, CRCP is not part of the Department's standard fix types, so its inputs and properties will not be included. Inputs for existing PCC Layers can be found in Chapter 13 – Existing Layer Inputs for Rehabilitation Design.

In the ME software, only one of the new concrete pavement types (JPCP or CRCP) can be designed per project. Begin a new concrete pavement design by selecting "New Pavement" for Design Type and the "Jointed Plain Concrete Pavement (JPCP)" Pavement Type in the General Information area of the main Project tab (see Chapter 4 – General Inputs). After this step, the selected pavement type PCC Layer will appear in the main Project tab. The ME software allows only one PCC Layer per new PCC design. Concrete related inputs are located in the PCC Layer tab and Design Properties tab within the main Project tab or by selecting the project folder of the Explorer menu. In the Explorer menu, view the PCC Layer tab by expanding the Pavement Structure folder drop-down node.

The JPCP Design Properties tab defines the parameters and properties of the JPCP design relative to the JPCP Layer. Material properties only pertaining to the JPCP Layer are defined within its own tab of the Pavement Structure. JPCP Properties tab inputs are outlined in Section 10.2 – JPCP Design Properties Tab Inputs and JPCP Layer inputs are outlined in Section 10.3 – JPCP (New) Layer Tab Inputs.

## 10.2 – JPCP Design Properties Tab Inputs

The parameters and properties pertaining to the JPCP design in relation to the JPCP Layer are accessed by selecting the JPCP Design Properties tab under the project folder of the Explorer pane. This area can also be accessed by selecting the Property Control drop-down menu of the main Project tab.

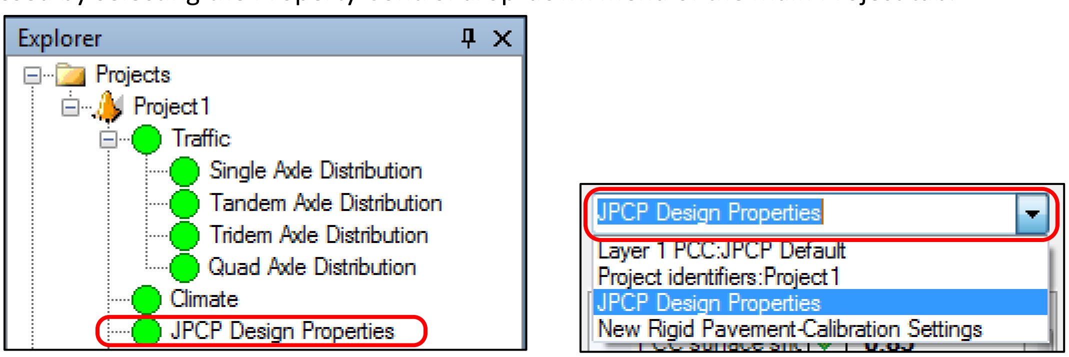



**Figure 10-1. JPCP Design Properties Tab Access Locations**

JPCP Design Properties tab areas (drop-down headings):

- JPCP Design

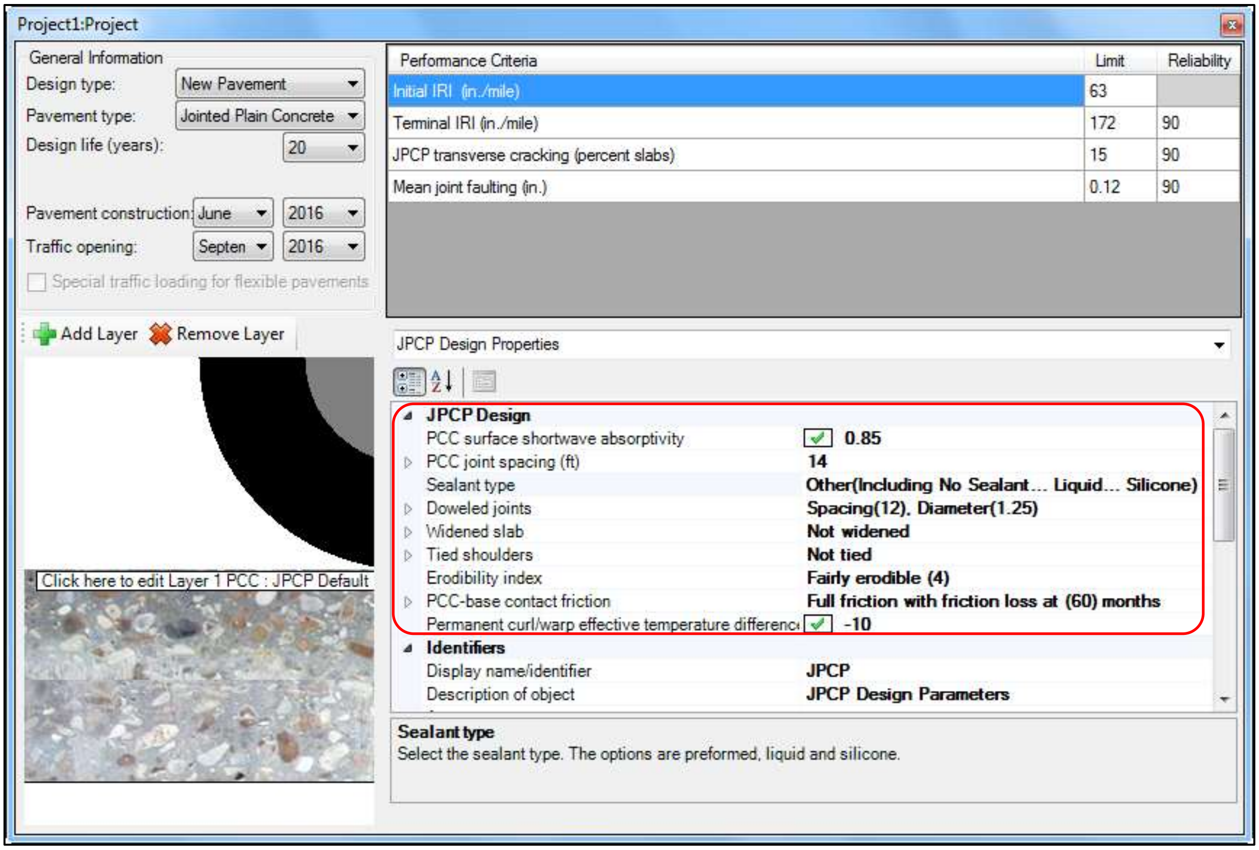



**Figure 10-2. JPCP Design Properties Tab Area**

### 10.2.1 – JPCP Design

<u>PCC surface shortwave absorptivity</u>

Enter the fraction of available solar energy absorbed by the concrete pavement surface. AASHTO recommends using the ME software default value of 0.85. Use this value.

<u>PCC joint spacing</u>

This input allows the user to define the transverse joint spacing and if that spacing is uniform (single spacing for all joints) or randomly spaced (multiple spacing values). Use the default selection, “False”. Selecting “True” indicates transverse joints are randomly spaced and allows the user to input up to four different spacing values. Selecting “False” indicates transverse joints are uniformly spaced and allows the user to input a single spacing value. MDOT utilizes a single standard joint spacing per the thickness of the concrete pavement.

For ‘Joint spacing’, enter the MDOT standard spacing (in feet) based on the ‘Thickness’ input of the JPCP Layer. Use the MDOT Standard Plan R-43 for guidance. Do not use the input areas ‘Spacing of joint …’ to indicate the uniform spacing value. These inputs are only used when “True” is selected.

Sealant type

Select the sealant type applied at the transverse joints. There are two options in the ME software, “Preformed” and “Other”. Selecting “Other” indicates liquid, silicone, or no sealant conditions. The MDOT standard sealant is hot-pour. This is most closely represented by the option “Other”. Select this option.

Doweled joints

This input allows the user to indicate whether transverse joints have dowels and if so, the diameter and spacing of those dowels. Use the default selection, “True”. Selecting “True” indicates that transverse joints have dowels and selecting “False” indicates that there are no dowels.

For ‘Dowel diameter’, enter the MDOT standard dowel diameter (in inches) based on the ‘Thickness’ input of the JPCP Layer. Use the MDOT Standard Plan R-40 for guidance.

For ‘Dowel spacing’, use the software default of 12”. Currently, gapped or unequal dowel spacing configurations are not modeled in the ME software. Likewise, construction irregularities such as improper dowel bar alignments are not modeled. While this can occur in the field, the software assumes that construction is completed as designed and expected.

Widened slab

This input allows the user to indicate whether the outer concrete slab is widened and if so, the width of the widened slab. This input is currently not used by MDOT. When using the ME widened slab input, improvement in pavement performance is exaggerated and terminal distress predictions are unrealistically now. If a widened slab is used, MDOT will reduce the concrete slab thickness by up to 1” (if other restrictions are not met first – see Section 14.3 – Assessing the Design Results) to manually account for the benefits of a widened slab. Leave this input as “Not widened” by using the ME software default “False” for “Is slab widened?”.

Tied shoulders

This input allows the user to indicate whether tied PCC shoulders are used. Use the software default “True” if concrete (including curb & gutter) shoulders are used or select “False” when asphalt shoulders are used.

If “True” is selected and there are tied concrete shoulders, use the ME software default of 50% for ‘Load transfer efficiency’. This input represents the long-term load transfer efficiency. According to MDOT FWD test results for concrete pavements 15 to 20 years old, most results indicated approximately 50% load transfer efficiency.

Erodibility index

Select one of the five index values that represent the resistance to erosion of the Base Layer under the PCC Layer, using an index on a scale of 1 (most resistant, least erodible) to 5 (least resistant, most erodible). An index value of 1 indicates erodibility 5 times less than a value of 2, and 2 indicates erodibility 5 times less than a value of 3, and so on. According to the 2004 NCHRP report 1-37A, *Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures*, granular base layers (including DGAB and OGDC, see Chapter 11 – Base/Subbase Layer Inputs) are best represented by the index value 4 (fairly erodible) and cement stabilized base layers (including dense and open graded, see Chapter 11 – Base/Subbase Layer Inputs) are best represented by the index value 1 (extremely erosion resistant). Therefore, per the Base Layer type, select 4 if using a granular base and select 1 if using a cement stabilized base.

PCC-base contact friction

This input allows the user to indicate whether there is full friction at the interface between the underlying base and PCC slab and if so, how long after construction that friction lasts. Use the software default "True" to indicate that there is full friction immediately after construction. This selection is recommended by AASHTO and MDOT. Selecting "False" would indicate that there is no friction, (do not select this option).

For 'Months until friction loss', enter the number of months after construction at which there is no longer friction between the PCC Layer and the Base Layer. This input is required when "True" is selected for 'PCC-Base full friction contact'. According to the 2004 NCHRP report 1-37A, *Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures*, 60 months or less is recommended for PCC designs. For this input, enter 60.

Permanent curl/warp effective temperature difference

This input indicates the equivalent temperature gradient difference between the top and bottom of the slab to describe the combined effect of the built-in curl and warp of the slab (at time of set), long-term creep of the slab, and settlement of the slab into the base. AASHTO recommends using the software default value of -10 °F, unless further testing is done. Research is available, but it is in terms of measured amount, not temperature differences. At this time, use the ME software default value of -10 °F.

## 10.3 – JPCP (New) Layer Tab Inputs

Inputs pertaining specifically to the JPCP Layer are accessed by selecting the JPCP Layer tab under the Pavement Structure folder of the project folder in the Explorer pane, by selecting the Property Control drop-down menu of the main Project tab, or by selecting the layer shown in the Pavement Structure display area of the main Project tab.

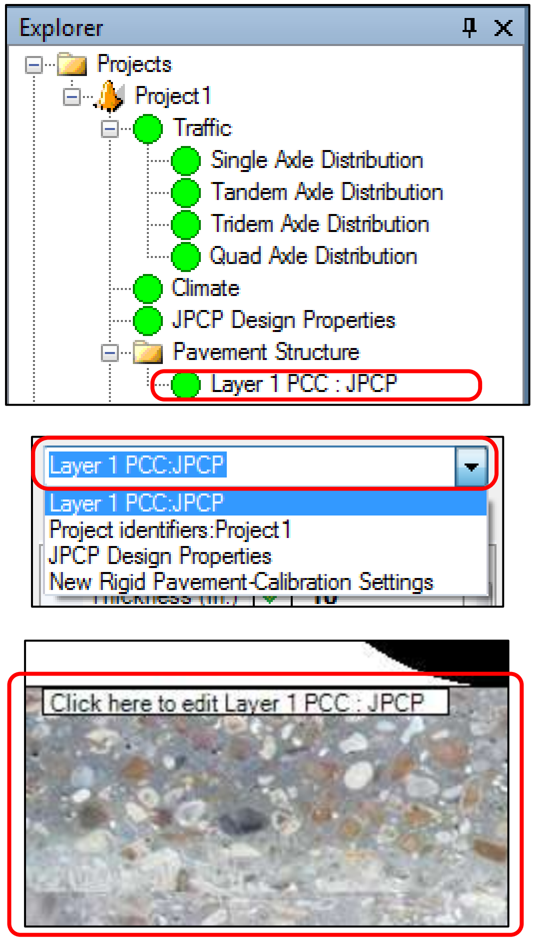



**Figure 10-3. JPCP (New) Layer Tab Access Locations**

JPCP Design Properties tab areas (drop-down headings):

- PCC
- Thermal
- Mix
- Strength

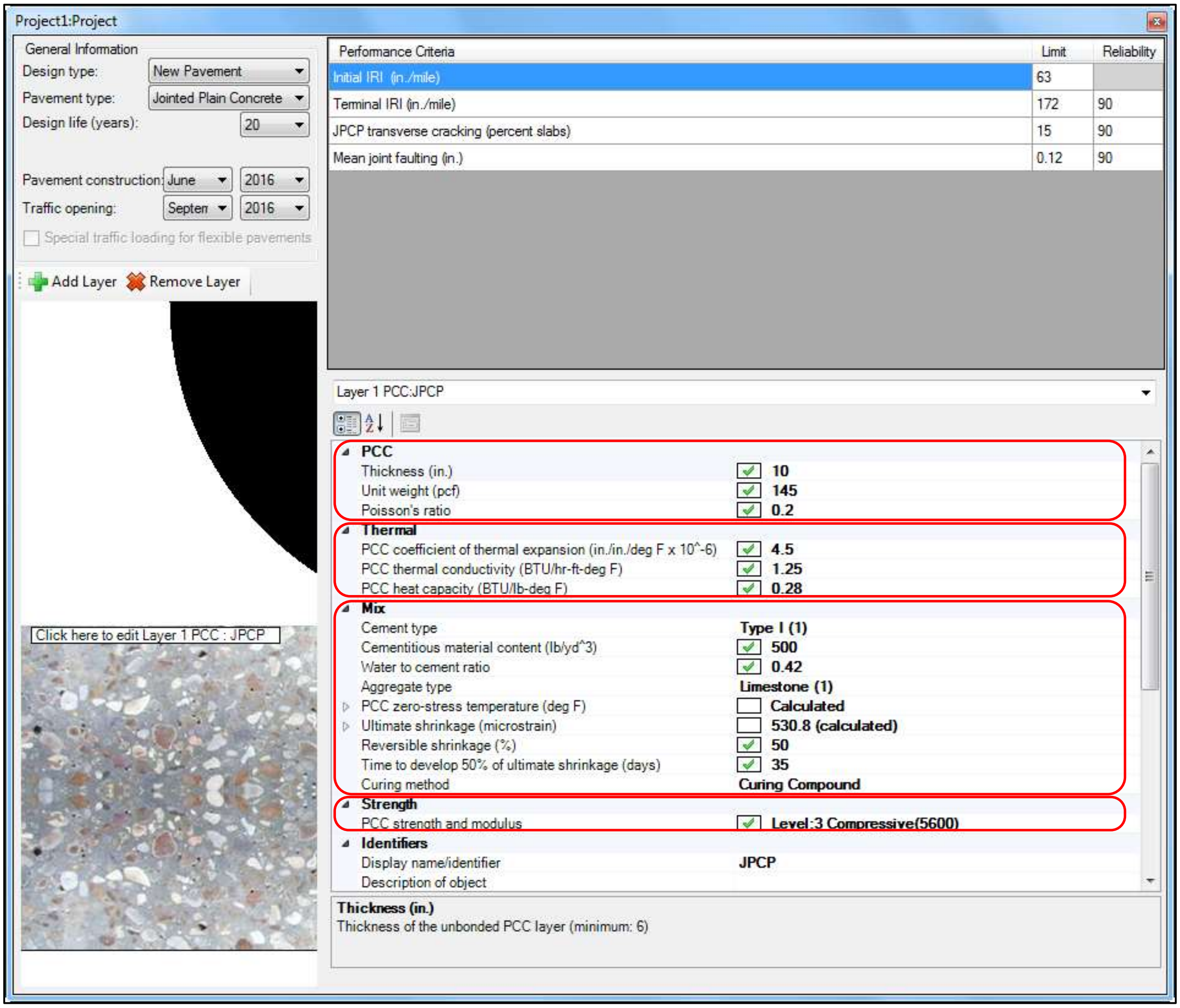



**Figure 10-4. JPCP (New) Layer Tab Area**

## 10.3.1 – PCC

Thickness

Enter the thickness, in inches, of the selected layer. The distress outputs are sensitive to this input. This input should be identified by the designer, following MDOT standards.

Unit weight (pcf)

Enter the unit weight of the mix in pounds per cubic foot. This value does not greatly vary for MDOT concrete mixes. Use the typical value of 145 lbs/ft$^3$.

Poisson's Ratio

Poisson's ratio is the ratio of perpendicular strain to axial strain when the material is placed under load. For PCC pavements, this is a constant value. Use the ME software default value of 0.2.

### 10.3.2 – Thermal

<u>PCC coefficient of thermal expansion</u>

Enter the expansion the PCC material undergoes with change in temperature. PCC coefficient of thermal expansion (CTE) is the increase in length per unit length of PCC for a unit increase in temperature, or in./in./°F. Note that this input is entered in the multiple of $10^{-6}$. Based on the coarse aggregate sources and types typically used throughout the state, it was determined that the entry depends on the MDOT region that the project is primarily located. For University and Metro Regions, use 5.0 and for all remaining regions (Bay, Grand, North, Southwest, and Superior) use 4.4.

Note that the CTE values within the MDOT report *Quantifying Coefficient of Thermal Expansion Values of Typical Hydraulic Cement Concrete Paving Mixtures* (Report RC-1503) were based on version 2.0 of the ME software and locally calibrated coefficients. However, MDOT is currently using version 2.3 of the ME software and global (default) concrete calibration coefficients. The test method for CTE changed from version 2.0 to 2.3. In the noted MDOT research project, test results were based on the outdated test procedure. The updated test method typically results in CTE values that are lower than those produced from the old procedure. The MDOT research found that most of the PCC aggregates used in Metro and University Regions were dolomite, while limestone was used in the rest of the state. Therefore, until MDOT conducts new testing per the updated test procedure, MDOT is using the recommended values for dolomite and limestone found in the ME Manual of Practice Level 3 inputs for ME version 2.3.

<u>PCC thermal conductivity</u>

Enter the thermal conductivity of the PCC Layer. This is the ability of the PCC material to conduct and transfer heat. It is used along with 'PCC heat capacity' (see below) to estimate the moisture and temperature gradients in the pavement layer. According to the 2004 NCHRP report 1-37A, *Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures*, conductivity only varies substantially with high moisture content and recommends a value of 1.25 BTU/hr-ft-˚F. For this input, use the ME software default value of 1.25 BTU/hr-ft-˚F.

<u>PCC heat capacity</u>

Enter the heat capacity of the PCC Layer. This is the amount of energy (heat) in BTU needed to increase the temperature of one pound of the material by one-degree Fahrenheit, or BTU/lb-°F. According to the 2004 NCHRP report 1-37A, *Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures*, 0.28 BTU/lb-°F is recommended for PCC designs. For this input, use the ME software default value of 0.28 BTU/lb-°F.

### 10.3.3 – Mix

<u>Cement type</u>

Select the type of cement used in the PCC mix. There are three options, "Type I (1)", "Type II (2)", or "Type III (3)". The most typical cement type used in MDOT pavements is Type I. Use the ME software default selection of "Type I (1)".

Cementitious material content

Enter the cementitious material weight per cubic yard of mixed concrete including fly ash, ground granulated blast furnace slag, or other supplementary cementitious materials. Based on current MDOT mixes being produced, the typical value is 500 $lbs/yd^3$. Use this value.

Water to cement ratio

Enter the ratio of the weight of water to the weight of cementitious materials in the PCC mix. The average value for as-constructed MDOT Metro Region concrete pavements from 2009 to 2012 was approximately 0.42. Further investigations may be required to identify whether ready-mix or portable plant water to cement ratios vary. At this time, use the ME software default value of 0.42.

Aggregate type

Select the predominant coarse aggregate type used in the PCC mix. There are seven options, “Quartzite (0)”, “Limestone (1)”, “Dolomite (2)”, “Granite (3)”, “Rhyolite (4)”, “Basalt (5)”, “Syenite (6)”, “Gabbro (7)”, and “Chert (8)”. The coarse aggregate used on most MDOT projects is limestone. Select “Limestone (1)”.

PCC zero-stress temperature

This input allows the user to enter the PCC zero-stress temperature, or as calculated by the ME software as a function of ‘Cementitious material content’ (see above) and average hourly temperatures for the month of construction. The zero-stress temperature is the PCC temperature at the time of set. Currently, there are no standard tests for this input. Use the ME software default selection of “True” and allow the software to internally calculate the PCC zero-stress temperature.

If “False” is selected, the ‘User-specified PCC set temperature’ input can be used to manually enter the zero-stress temperature value. Do not select “False”.

Ultimate shrinkage

This input allows the user to enter the PCC ultimate shrinkage, or as calculated by the ME software as a function of ‘Cementitious material content’ and ‘Water to cement ratio’ (see above). The ultimate shrinkage is the long-term (approximately 5 or more years) shrinkage strain that the PCC is expected to develop. Currently, there are no long-term tests for this input (AASHTO T160 measures approximately 180 day shrinkage). Use the ME software default selection of “True” and allow the software to internally calculate the ultimate shrinkage.

If “False” is selected, the ‘User-specified PCC ultimate shrinkage’ input can be used to manually enter the ultimate shrinkage value. Do not select “False”.

Reversible shrinkage

Enter the percentage of ultimate shrinkage that is “recoverable” upon re-wetting of the concrete due to changes in PCC humidity and moisture. According to the 2004 NCHRP report 1-37A, *Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures*, 50% is recommended for PCC designs. There is limited information to suggest a different value. Use the ME software default value of 50%.

Time to develop 50% of ultimate shrinkage

Enter the number of days it takes for 50% of the ultimate shrinkage to develop. According to the 2004 NCHRP report 1-37A, *Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures*, 35 days is recommended for PCC designs. Use the ME software default value of 35 days.

Curing method

Select the curing method of the PCC Layer. There are two options, 'Wet Curing' or 'Curing Compound'. The method used on most MDOT projects is 'Curing Compound'. Use the ME software default selection of 'Curing Compound'.

### 10.3.4 – Strength

PCC strength and modulus

This input allows the user to define the strength and modulus properties of the PCC Layer. The options and inputs within its drop-down menu vary depending on the selected 'PCC strength input level' (shown at the top). The Level 1 selection allows the user to enter test results for 'Modulus of rupture' and 'Elastic modulus' at 7, 14, 28, and 90 days as well as the 20-year/28-day ratio. The Level 2 selection allows the user to enter test results for 'Compressive strength' at 7, 14, 28, and 90 days as well as the 20-year/28-day ratio. The Level 3 selection allows the user to enter or allow the software to internally calculate the '28-Day PCC elastic modulus', and enter either the '28-Day PCC modulus of rupture' or '28-Day PCC compressive strength'. Unchecking the '28-Day PCC elastic modulus' check box indicates that the software will internally calculate the input based on the compressive strength or modulus of rupture value. The software automatically converts all entered compressive strength values to modulus of rupture values by using the following equation:

$$\textit{Modulus of Rupture} = 9.5 * \sqrt{(\textit{Compressive Strength})}$$

Currently, MDOT does not collect the level of data required for Levels 1 or 2. MDOT does not collect compressive strengths at ages other than at 28-days and modulus or rupture information is very limited. The Level 3 option does include the 28-day compressive strength, which is collected by MDOT. The typical value for MDOT concrete pavements is approximately 5600 psi.

As a result, select the Level 3 option, uncheck the box for '28-Day PCC elastic modulus' (to allow software internal calculation), and select the option for '28-Day PCC compressive strength' and enter 5600 in the value field. Do not select the Level 1 or 2 options.

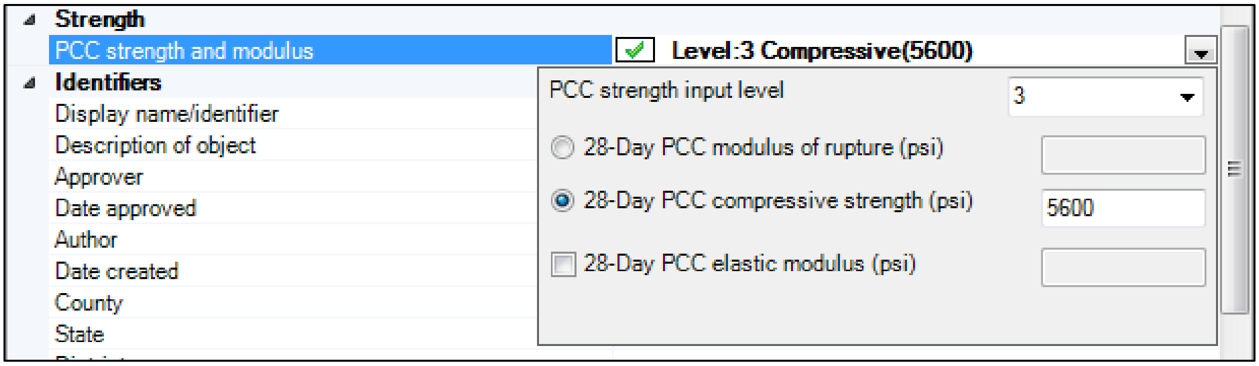



**Figure 10-5. Strength window**

# Chapter 11 – Base/Subbase Layer Inputs

**Table 11-1. Recommended Dense Graded Aggregate Base Inputs**

| Input | | | | Units | Recommended Value |
|---|---|---|---|---|---|
| Unbound | **Thickness** | | | **inches** | **Aggregate base layer = 6**<br><br>**Crush & shape layer = average existing HMA thickness plus 1** |
| | Poisson's ratio | | | | 0.35 *(software default)* |
| | Coefficient of lateral earth pressure | | | | 0.5 *(software default)* |
| Modulus | Resilient Modulus – Level 2 or 3 | Input Level | | | SELECT (2 or 3) *(software default)* |
| | | Analysis Types | | | Modify input values by temperature/moisture *(software default)* |
| | | Method | | | Resilient Modulus *(software default)* |
| | | **Value field** | | **psi** | **Aggregate base = 33,000**<br><br>**Crush & shape layer = 125,000** |
| Sieve | Gradation & Other Engineering Properties | **Percent Passing (sieve table)** | **1.5"** | **% passing** | **100** |
| | | | **1"** | **% passing** | **94.2** |
| | | | **½"** | **% passing** | **67.7** |
| | | | **No. 8** | **% passing** | **33.2** |
| | | | **No. 200** | **% passing** | **7.7** |
| | | **Liquid Limit** | | | **0** |
| | | **Plasticity Index** | | | **0** |
| | | Is layer compacted? | | | Check box |
| | | Maximum dry unit weight | | $lbs/ft^3$ | Leave unchecked box (software will calculate) *(software default)* |
| | | Saturated hydraulic conductivity | | ft/hr | Leave unchecked box (software will calculate) *(software default)* |
| | | Specific gravity of solids | | | Leave unchecked box (software will calculate) *(software default)* |
| | | Optimum gravimetric water content | | % | Leave unchecked box (software will calculate) *(software default)* |
| | | User-defined Soil Water Characteristic Curve (SWCC) | | | Leave unchecked box (software will calculate) *(software default)* |

***Bold** = sensitive input

**Table 11-2. Recommended Open Graded Drainage Course Inputs**

| Input | | | | Units | Recommended Value |
|---|---|---|---|---|---|
| Unbound | **Thickness** | | | **inches** | **<u>Aggregate base layer</u> = 6 (except for Metro Section, which will be 16)** |
| | Poisson's ratio | | | | 0.35 *(software default)* |
| | Coefficient of lateral earth pressure | | | | 0.5 *(software default)* |
| Modulus | Resilient Modulus – Level 2 or 3 | Input Level | | | SELECT (2 or 3) *(software default)* |
| | | Analysis Types | | | Modify input values by temperature/moisture *(software default)* |
| | | Method | | | Resilient Modulus *(software default)* |
| | | **Value field** | | **psi** | **33,000** |
| Sieve | Gradation & Other Engineering Properties | **Percent Passing (sieve table)** | **1.5"** | **% passing** | **100** |
| | | | **1"** | **% passing** | **93.5** |
| | | | **½"** | **% passing** | **58.8** |
| | | | **No. 8** | **% passing** | **23.6** |
| | | | **No. 30** | **% passing** | **13.7** |
| | | | **No. 200** | **% passing** | **4.2** |
| | | **Liquid Limit** | | | **0** |
| | | **Plasticity Index** | | | **0** |
| | | Is layer compacted? | | | Check box |
| | | Maximum dry unit weight | | $lbs/ft^3$ | Leave unchecked box (software will calculate) *(software default)* |
| | | Saturated hydraulic conductivity | | ft/hr | Leave unchecked box (software will calculate) *(software default)* |
| | | Specific gravity of solids | | | Leave unchecked box (software will calculate) *(software default)* |
| | | Optimum gravimetric water content | | % | Leave unchecked box (software will calculate) *(software default)* |
| | | User-defined Soil Water Characteristic Curve (SWCC) | | | Leave unchecked box (software will calculate) *(software default)* |

***Bold** = sensitive input

**Table 11-3. Recommended Sand Subbase Inputs**

<table>
<tr><th colspan="4">Input</th><th>Units</th><th>Recommended Value</th></tr>
<tr><td rowspan="3">Unbound</td><td colspan="3">Thickness</td><td>inches</td><td><u>HMA design</u> = 18 (except for Metro Section, which will be 8)<br><br><u>Concrete design</u> = 10 (except for Metro Section, which will be 0)</td></tr>
<tr><td colspan="3">Poisson's ratio</td><td></td><td>0.35 (software default)</td></tr>
<tr><td colspan="3">Coefficient of lateral earth pressure</td><td></td><td>0.5 (software default)</td></tr>
<tr><td rowspan="4">Modulus</td><td rowspan="4">Resilient Modulus – Level 2 or 3</td><td colspan="2">Input Level</td><td></td><td>SELECT (2 or 3) (software default)</td></tr>
<tr><td colspan="2">Analysis Types</td><td></td><td>Modify input values by temperature/moisture (software default)</td></tr>
<tr><td colspan="2">Method</td><td></td><td>Resilient Modulus (software default)</td></tr>
<tr><td colspan="2">Value field</td><td>psi</td><td>20,000</td></tr>
<tr><td rowspan="11">Sieve</td><td rowspan="11">Gradation & Other Engineering Properties</td><td rowspan="3">Percent Passing (sieve table)</td><td>1"</td><td>% passing</td><td>99.8</td></tr>
<tr><td>No. 100</td><td>% passing</td><td>15.6</td></tr>
<tr><td>No. 200</td><td>% passing</td><td>4.6</td></tr>
<tr><td colspan="2">Liquid Limit</td><td></td><td>0</td></tr>
<tr><td colspan="2">Plasticity Index</td><td></td><td>0</td></tr>
<tr><td colspan="2">Is layer compacted?</td><td></td><td>Check box</td></tr>
<tr><td colspan="2">Maximum dry unit weight</td><td>lbs/ft$^3$</td><td>Leave unchecked box (software will calculate) (software default)</td></tr>
<tr><td colspan="2">Saturated hydraulic conductivity</td><td>ft/hr</td><td>Leave unchecked box (software will calculate) (software default)</td></tr>
<tr><td colspan="2">Specific gravity of solids</td><td></td><td>Leave unchecked box (software will calculate) (software default)</td></tr>
<tr><td colspan="2">Optimum gravimetric water content</td><td>%</td><td>Leave unchecked box (software will calculate) (software default)</td></tr>
<tr><td colspan="2">User-defined Soil Water Characteristic Curve (SWCC)</td><td></td><td>Leave unchecked box (software will calculate) (software default)</td></tr>
</table>

***Bold** = sensitive input

**Table 11-4. Recommended Cement Stabilized Base Inputs**

<table>
<tr><th colspan="2">Input</th><th>Units</th><th>Recommended Value</th></tr>
<tr><td rowspan="3">General</td><td>Thickness</td><td>inches</td><td>5</td></tr>
<tr><td>Unit Weight</td><td>lbs./cu. ft.</td><td>Open-graded = 105<br>Dense-graded = 135</td></tr>
<tr><td>Poisson's ratio</td><td></td><td>0.2 ( software default)</td></tr>
<tr><td>Strength</td><td>Elastic/Resilient Modulus</td><td>psi</td><td>1,000,000</td></tr>
<tr><td rowspan="2">Thermal</td><td>Thermal Conductivity</td><td>BTU/ hr.-ft.-˚F</td><td>1.25 ( software default)</td></tr>
<tr><td>Heat Capacity</td><td>BTU/ lb.-˚F</td><td>0.28 ( software default)</td></tr>
</table>

## 11.1 – Introduction

The base and subbase are granular layers that provide support, drainage, and frost-heave resistance for the paved surface layer.  Dense-graded aggregate base (DGAB) is typically used under HMA pavements, while open-graded drainage course (OGDC) is typically used under concrete pavements.  Sand subbase is used under both pavement types (under the base and above the subgrade).

The MDOT standard base/subbase combination is 6” DGAB/18” sand under asphalt pavements and 6” OGDC/10” sand under concrete pavements.  In the Metro Region, the standard combination (known as the Metro Section) is 16” OGDC/8” sand under asphalt pavements and 16” OGDC (only) under concrete pavements.  In the Grand Region, the base/subbase combination under asphalt pavements is 6” OGDC/18” sand.

Both the base and subbase layers are inserted in to the ME design as a “non-stabilized base” layer using the Add Layer function (see Section 2.6.4.4 – Pavement Structure).  Tables 11-1 through 11-3 should then be used as the inputs for the appropriate layer.  If a starter design is used as described in Chapter 3, these layers will already be inserted in the design.

For some high truck volume routes, the use of a cement-stabilized base for the concrete design may be considered.  The cement-stabilized base is inserted in the ME design as a chemically stabilized layer and the values listed in Table 11-4 should be utilized.

The base and subbase layer inputs can be accessed by selecting either layer under the Pavement Structure folder in the Explorer menu, by selecting the Property Control drop-down menu in the Project Tab pane, or by selecting the layer in the Pavement Structure display area as shown in Figure 11-1.

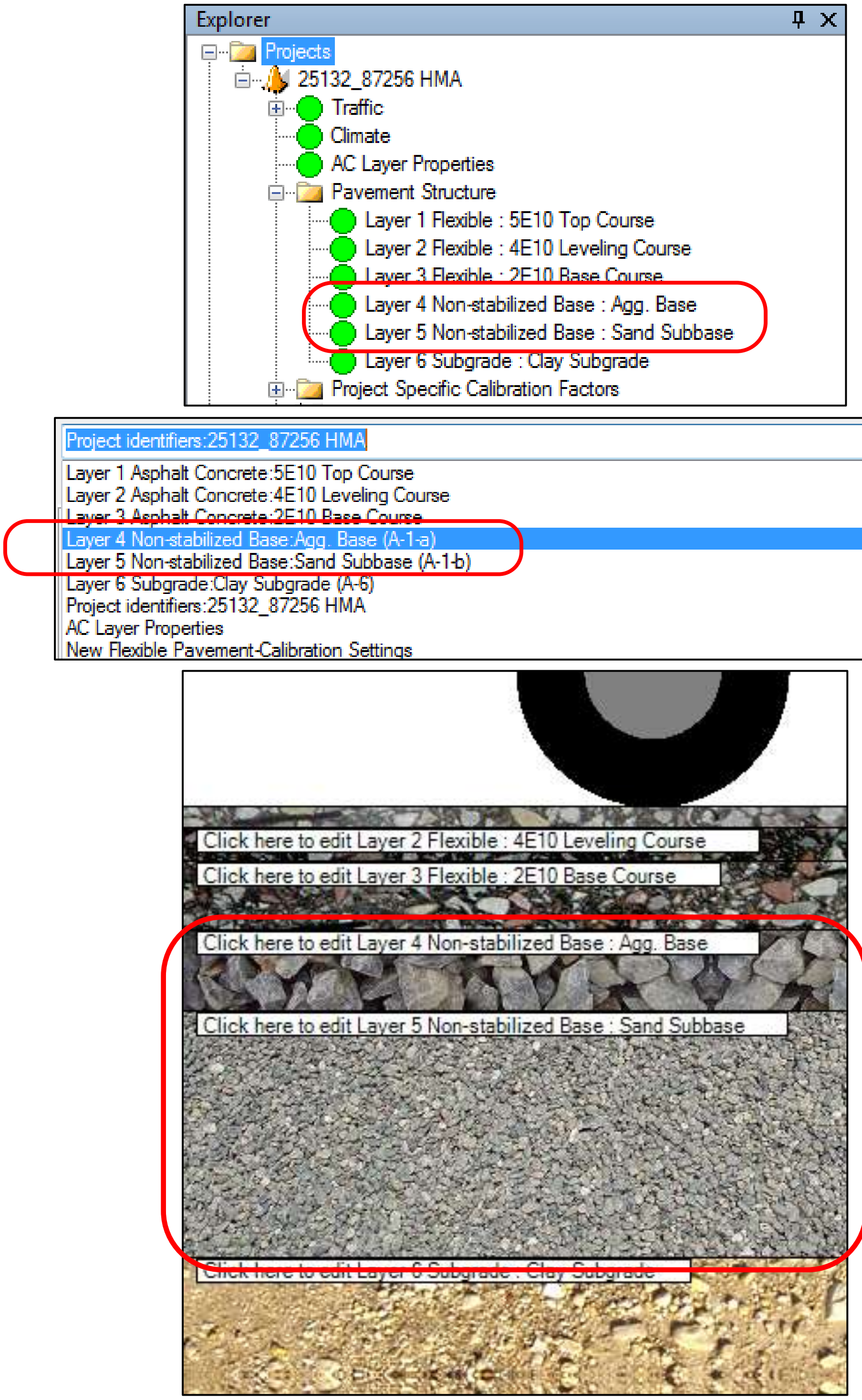



**Figure 11-1. Base and Subbase Layer Access Locations**

## 11.2 – Base Inputs

The required inputs are the same regardless of whether the base layer is a DGAB or an OGDC. The input values, however, for each of these material types may differ as noted below and in Tables 11-1 and 11-2. The layer inputs as seen in the Project Tab pane can be seen in Figure 11-2.

| | |
|---|---|
| **Unbound** | |
| Layer thickness (in.) | 6 |
| Poisson's ratio | 0.35 |
| Coefficient of lateral earth pressure (k0) | 0.5 |
| **Modulus** | |
| Resilient modulus (psi) | 33000 |
| **Sieve** | |
| Gradation & other engineering properties | A-1-a |
| **Identifiers** | |
| Display name/identifier | Agg. Base |

**Figure 11-2. Base Layer Inputs**

### 11.2.1 – Unbound

Thickness

Enter the thickness, in inches, of the base layer. The distress outputs are sensitive to this input. The standard thickness is 6” for both DGAB and OGDC. The exception to this is in the Metro Region where 16” of OGDC is used under both HMA and concrete.

Poisson’s Ratio

Poisson’s ratio is the ratio of perpendicular strain to axial strain when the material is placed under load. Use the software default value of 0.35.

Coefficient of Lateral Earth Pressure

This input represents the pressure the layer exerts in the horizontal plane. Use the software default value of 0.5.

### 11.2.2 – Modulus

To access the modulus inputs, click in the box next to the modulus value to obtain the drop-down arrow, and then click the arrow. The modulus inputs box can be seen in Figure 11-3.

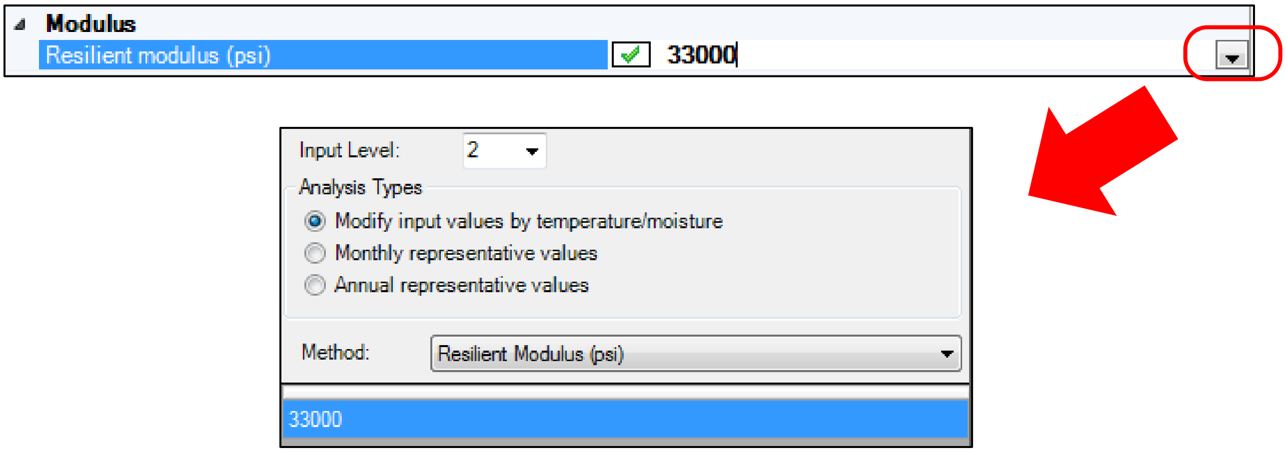



**Figure 11-3. Modulus Inputs**

Input Level

Level 1 is not available as a choice. Levels 2 and 3 are identical except that level 2 has additional options available for the 'Analysis Type' and 'Method' inputs. These additional choices (noted below) will not be utilized so levels 2 and 3 essentially become the same. The designer may choose either level.

Analysis Type

This input tells the software whether the Enhanced Integrated Climatic Model (EICM) will be utilized on this layer. For level 3, there are two choices: "Modify Inputs By Temperature/Moisture" (which uses the EICM) or "Annual Representative Value" (which does not use the EICM). Level 2 adds one more choice: "Monthly Representative Values," which does not use the EICM. Select the "Modify Inputs By Temperature/Moisture" option for either level.

Method

With this input, other properties can be entered that will then be converted to resilient modulus using correlations internal to the software. For level 3, only resilient modulus is available as a choice. Level 2 has the following choices:

- Resilient Modulus
- California Bearing Ratio (CBR)
- R-value
- Layer coefficient – ai
- Dynamic Cone Penetrometer (DCP) penetration
- Plasticity Index and Gradation (which are entered in the 'Gradation & Other Engineering Properties' area – see Section 11.2.3 – Gradation & Other Engineering Properties)

Choose "resilient modulus" for this input for either level.

Value
The resilient modulus of the base layers was determined as part of the research project *Backcalculation of Unbound Granular Layer Moduli* (Report RC-1548). This project recommended a value of 33,000 psi for DGAB and OGDC, which was adopted. The distress outputs for asphalt designs are sensitive to this input.

### 11.2.3 – Gradation & Other Engineering Properties

This area contains several other layer property inputs as seen in Figure 11-4. To access this area, click in the box containing the AASHTO classification to obtain the drop-down arrow, and then click the arrow.

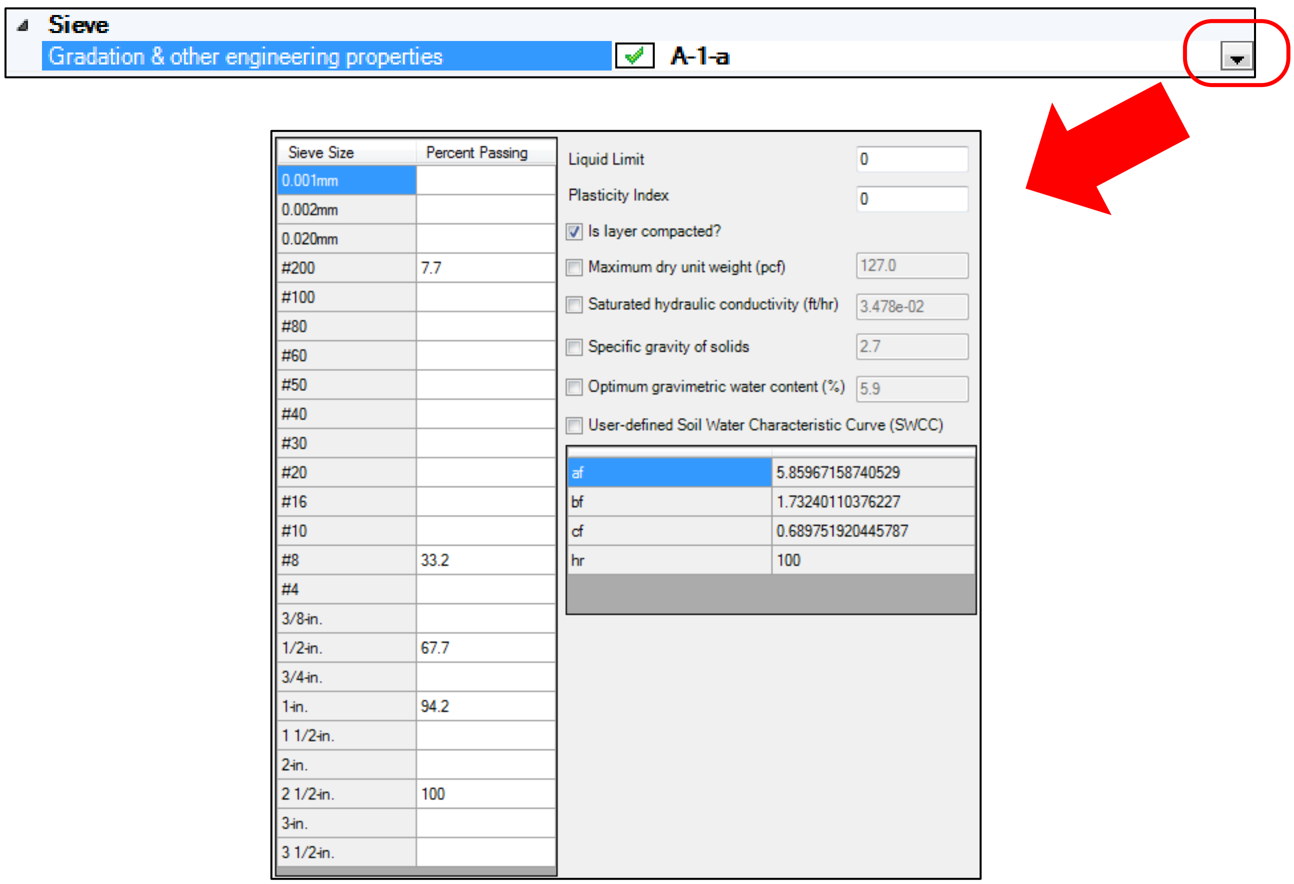



**Figure 11-4. Gradation and Other Properties Input Box**

Sieve
The percent passing various sieve sizes is to be entered. All the typical sieve sizes from 3.5” down to 0.001 mm are available, however, only a minimum of three need be entered. Table 11-5 contains the gradations to be used for both DGAB and OGDC. The distress outputs are sensitive to this input.

**Table 11-5. Base Course Aggregate Gradations**

| Sieve | Dense Graded Agg. Base % passing | Open Graded Drainage Course % passing |
|---|---|---|
| 1.5” | 100 | 100 |
| 1” | 94.2 | 93.5 |
| ½” | 67.7 | 58.8 |
| No. 8 | 33.2 | 23.6 |
| No. 30 | | 13.7 |
| No. 200 | 7.7 | 4.2 |

Liquid Limit

The liquid limit of the material is to be entered. Because of the low amount passing the No. 200 sieve, DGAB and OGDC are not considered “clayey” materials and therefore do not have a liquid limit. Use 0 for both material types. The distress outputs for asphalt designs are sensitive to this input.

Plasticity Index

Plasticity Index is the difference between the liquid limit and the plastic limit. Because of the low amount passing the No. 200 sieve, DGAB and OGDC are not considered “clayey” materials and thus do not have a liquid limit or plastic limit. Therefore, they do not have a plasticity index. Use 0 for both material types. The distress outputs are sensitive to this input.

Is Layer Compacted?

MDOT requires the base layers to be compacted to a certain density, so check the box for this input for both material types to indicate that they are compacted.

Maximum Dry Unit Weight

This is the unit weight of the material at its maximum density (zero air voids). Leave the box unchecked to allow the software to calculate this value based on other entered properties.

Saturated Hydraulic Conductivity

This input is a measure of the water movement properties within a saturated granular material under a hydraulic gradient. Leave the box unchecked to allow the software to calculate this value based on other entered properties.

Specific Gravity of Solids

This input is the ratio of the density of the solids portion of the material (i.e. minus the water) to that of water. Leave the box unchecked to allow the software to calculate this value based on other entered properties.

Optimum Gravimetric Water Content

This input is the water content (by weight) that produces the maximum unit weight for the material. Leave the box unchecked to allow the software to calculate this value based on other entered properties.

User-Defined Soil Water Characteristic Curve

The soil water characteristic curve is the relationship between the material's water content and its suction properties. The user can enter the values for the four coefficients required for the curve. Leave the box unchecked to allow the software to calculate the coefficients based on other entered properties.

## 11.3 – Subbase Inputs

The sand subbase properties are the same regardless of whether it is used in an HMA or concrete design. The one exception to this is the thickness. The required inputs are the same as is shown in Figure 11-2.

### 11.3.1 – Unbound

Thickness

Enter the thickness, in inches, of the subbase layer. The standard thickness is 18" under HMA pavements and 10" under concrete pavements. For the Metro Section, use 8" under HMA pavements and no subbase is used under concrete pavements.

Poisson's Ratio

Poisson's ratio is the ratio of perpendicular strain to axial strain when the material is placed under load. Use the software default value of 0.35.

Coefficient of Lateral Earth Pressure

This input represents the pressure the layer exerts in the horizontal plane. Use the software default value of 0.5.

### 11.3.2 – Modulus

To access the modulus inputs, click in the box next to the modulus value to obtain the drop-down arrow, and then click the arrow. The required inputs are the same as is shown in Figure 11-3.

Input Level

Level 1 is not available as a choice. Levels 2 and 3 are identical except that with level 2, there are additional choices available for the 'Analysis Type' and 'Method' inputs. These additional choices (noted below) will not be utilized so levels 2 and 3 essentially become the same. The designer may choose either level.

Analysis Types

This input tells the software whether the Enhanced Integrated Climatic Model (EICM) will be utilized on this layer. For level 3, there are two choices: "Modify Inputs By Temperature/Moisture" (which uses the EICM) or "Annual Representative Value" (which does not use the EICM). Level 2 adds one more choice:

"Monthly Representative Values," which does not use the EICM. Select the "Modify Inputs By Temperature/Moisture" option for either level.

Method

With this input, other properties can be entered that will then be converted to resilient modulus using correlations internal to the software. For level 3, only resilient modulus is available as a choice. Level 2 has the following choices:

- Resilient Modulus (psi)
- California Bearing Ratio (CBR)
- R-value
- Layer coefficient – ai
- Dynamic Cone Penetrometer (DCP) penetration
- Plasticity Index and Gradation (which are entered in the 'Gradation & Other Engineering Properties' area – see Section 11.3.3 – Gradation & Other Engineering Properties)

Choose "Resilient Modulus (psi)" for this input for either level.

Value

The resilient modulus of the base layers was determined as part of the research project *Backcalculation of Unbound Granular Layer Moduli* (Report RC-1548). This project recommended a value of 20,000 psi, which was adopted. The distress outputs for rehabilitation designs are sensitive to this input.

### 11.3.3 – Gradation & Other Engineering Properties

This area contains several other layer property inputs as seen in Figure 11-4. To access this area, click in the box containing the AASHTO classification to obtain the drop-down arrow, and then click the arrow. The required inputs are the same as is shown in Figure 11-4.

Sieve

The percent passing various sieve sizes is to be entered. All the typical sieve sizes from 3" down to 0.001" are available, however, only a minimum of three need be entered. Table 11-6 contains the gradations to be used for sand subbase. The distress outputs are sensitive to the No. 200 sieve.

**Table 11-6. Sand Subbase Aggregate Gradations**

| Sieve | Open Graded Drainage Course % passing |
|---|---|
| 1" | 99.8 |
| No. 100 | 15.6 |
| No. 200 | 4.6 |

Liquid Limit

The liquid limit of the material is to be entered. Because of the low amount passing the No. 200 sieve, sand subbase is not considered a "clayey" material and therefore does not have a liquid limit. Use 0 for this input.

Plasticity Index

Plasticity Index is the difference between the liquid limit and the plastic limit. Because of the low amount passing the No. 200 sieve, sand subbase is not considered a "clayey" material and thus does not have a liquid limit or plastic limit. Therefore, it does not have a plasticity index. Use 0 for this input. The distress outputs are sensitive to this input.

Is Layer Compacted?

MDOT requires the subbase layer to be compacted to a certain density, so check the box for this input to indicate that it is compacted.

Maximum Dry Unit Weight

This is the unit weight of the material at its maximum density (zero air voids). Leave the box unchecked to allow the software to calculate this value based on other entered properties.

Saturated Hydraulic Conductivity

This input is a measure of the water movement properties within a saturated material under a hydraulic gradient. Leave the box unchecked to allow the software to calculate this value based on other entered properties.

Specific Gravity of Solids

This input is the ratio of the density of the solids portion of the material (i.e. minus the water) to that of water. Leave the box unchecked to allow the software to calculate this value based on other entered properties.

Optimum Gravimetric Water Content

This input is the water content (by weight) that produces the maximum unit weight for the material. Leave the box unchecked to allow the software to calculate this value based on other entered properties.

User-Defined Soil Water Characteristic Curve

The soil water characteristic curve is the relationship between the soils water content and its suction properties. The user can enter the values for the four coefficients required for the curve. Leave the box unchecked to allow the software to calculate the coefficients based on other entered properties.

### 11.4 – Cement Stabilized Base Inputs

The required inputs for a cement stabilized base can be seen in Figure 11-5. The inputs to be used for each are found in Table 11-4.

| | |
|---|---|
| **General** | |
| Layer thickness (in.) | 5 |
| Unit weight (pcf) | 105 |
| Poisson's ratio | 0.2 |
| **Strength** | |
| Elastic/resilient modulus (psi) | 1000000 |
| **Thermal** | |
| Thermal conductivity (BTU/hr-ft-deg F) | 1.25 |
| Heat capacity (BTU/lb-deg F). | 0.28 |

**Figure 11-5. Chemically Stabilized Base Layer Inputs**

#### 11.4.1 – General

Thickness

Enter the thickness, in inches, of the cement stabilized layer. Use 5 inches.

Unit Weight

This input is the density of the layer in pounds per cubic foot. This input will vary depending on whether the stabilized layer is an open-graded or dense-graded gradation. For an open-graded stabilized base use 105 pounds per cubic foot. For a dense-graded stabilized base use 135 pounds per cubic foot.

Poisson's Ratio

Poisson's ratio is the ratio of perpendicular strain to axial strain when the material is placed under load. Use the software default value of 0.2.

#### 11.4.2 – Strength

Elastic/Resilient Modulus

This input defines the modulus of the cement stabilized layer in pounds per square inch (psi). Use 1,000,000 psi.

#### 11.4.3 – Thermal

Thermal Conductivity

Thermal conductivity is a measure of a material's propensity to conduct heat. Use the software default of 1.25 BTU per hour-foot-˚F.

Heat Capacity

Heat capacity is the amount of heat in BTU needed to increase the temperature of one pound of the material by one-degree Fahrenheit. Use the software default of 0.28 BTU per pound-˚F.

# Chapter 12 – Subgrade Layer Inputs

**Table 12-1. Recommended Subgrade Inputs**

| Input | | | Units | Recommended Value |
|---|---|---|---|---|
| Unbound | Thickness | | inches | N/A (software will set as semi-infinite) *(software default)* |
| | Poisson's ratio | | | 0.35 *(software default)* |
| | Coefficient of lateral earth pressure | | | 0.5 *(software default)* |
| Modulus | Resilient Modulus – Level 2 or 3 | Input Level | | SELECT (2 or 3) *(software default)* |
| | | Analysis Type | | Annual representative values (third option) |
| | | Method | | Resilient Modulus *(software default)* |
| | | **Value field** | **psi** | **Typical of the designated material (see Table 12-2)** |
| Sieve | Gradation & Other Engineering Properties | **Percent Passing (sieve table)** | **% passing** | **Typical of the designated material (see Table 12-3)** |
| | | **Liquid Limit** | | **Typical of the designated material (see Table 12-4)** |
| | | **Plasticity Index** | | **Typical of the designated material (see Table 12-5)** |
| | | Is layer compacted? | | Check box |
| | | Maximum dry unit weight | $lbs/ft^3$ | *Typical of the designated material (see Table 12-6)* |
| | | Saturated hydraulic conductivity | ft/hr | Leave unchecked box (software will calculate) *(software default)* |
| | | Specific gravity of solids | | Leave unchecked box (software will calculate) *(software default)* |
| | | Optimum gravimetric water content | % | Leave unchecked box (software will calculate) *(software default)* |
| | | User-defined Soil Water Characteristic Curve (SWCC) | | Leave unchecked box (software will calculate) *(software default)* |

***Bold** = sensitive input

## 12.1 – Introduction

The subgrade layer is the bottom foundation layer upon which the other layers in the pavement cross-section are built. The material type is generally the native soil type in the general area. The exception to this would be areas that require undercutting due to the native soil having undesirable properties for supporting a pavement. Generally, MDOT has used the Unified Soil Classification System (USCS) for identifying the subgrade soil type. The inputs recommended in Tables 12-1 through 12-6 follow this system. It should be noted, however, that the Pavement ME Design software will display the AASHTO classification based on the gradation and other properties entered for the layer. The ME software requires that the bottom layer be a subgrade or bedrock layer.

The subgrade layer is inserted in to the ME design as a "subgrade" layer using the Add Layer function (see Section 2.6.4.4 – Pavement Structure). Table 12-1 should then be used as the inputs for the subgrade type. If a starter design is used as described in Chapter 3, a subgrade layer will already be inserted in the design. However, the subgrade type in the starter design may not be correct for the project being designed, so the correct type will need to be imported. See 3.1.8 – Step 8: Add/Delete Layers; Change Material Inputs for a discussion on the location of pre-created layers and Section 2.6.2.3 – Import/Export for a description of how to import.

The subgrade layer inputs can be accessed by selecting the layer under the Pavement Structure folder in the Explorer menu, by selecting the Property Control drop-down menu in the Project Tab pane, or by selecting the layer in the Pavement Structure display area as shown in Figure 12-1.

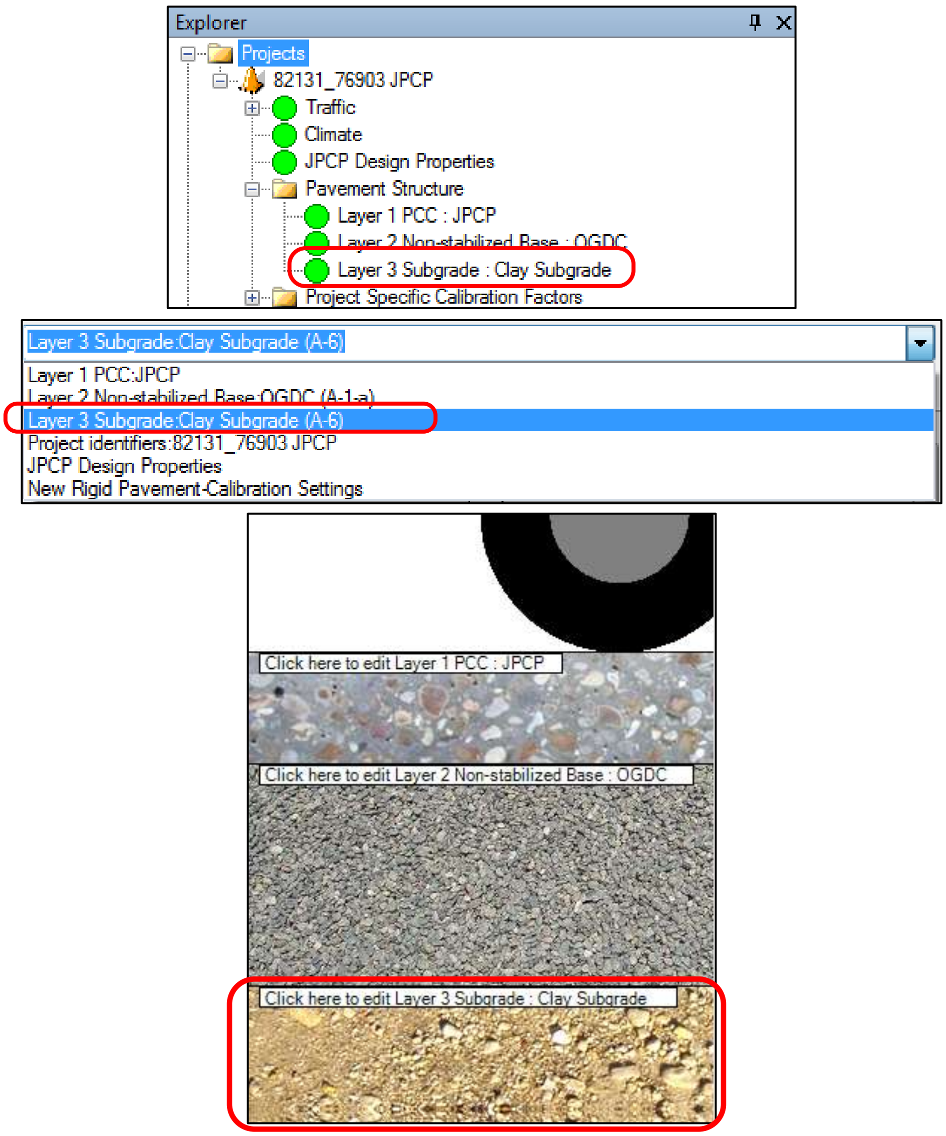



**Figure 12-1. Subgrade Layer Access Locations**

## 12.2 – Subgrade Inputs

The layer inputs as seen in the Project Tab pane can be seen in Figure 12-2. The types of inputs are the same regardless of the subgrade type. However, the individual inputs will vary as seen in Table 12-1 and Figure 12-2 below.

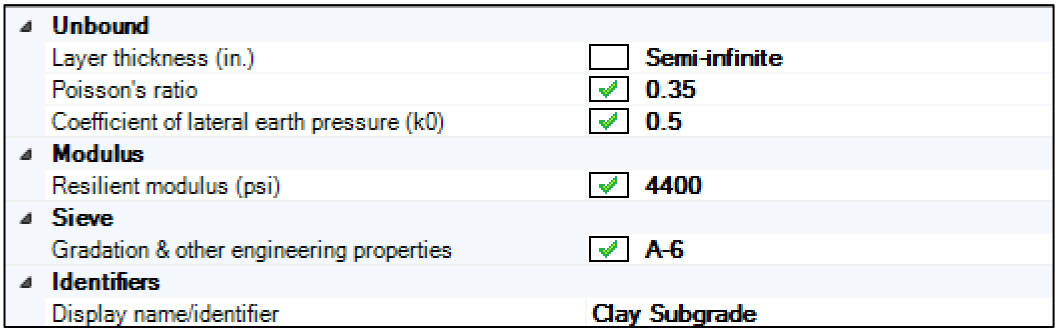



**Figure 12-2. Subgrade Layer Inputs**

### 12.2.1 – Unbound Properties

Thickness

For MDOT designs the subgrade layer should be the last, or bottom, layer. Pavement ME Design assumes the bottom layer to be semi-infinite in depth, so a thickness is not needed.

Poisson’s Ratio

Poisson’s ratio is the ratio of perpendicular strain to axial strain when the material is placed under load. Use the software default value of 0.35.

Coefficient of Lateral Earth Pressure

This input represents the pressure the layer exerts in the horizontal plane. Use the software default value of 0.5.

### 12.2.2 – Modulus

To access the modulus inputs, click in the box next to the modulus value to obtain the drop-down arrow, and then click the arrow. The modulus inputs box can be seen in Figure 12-3.

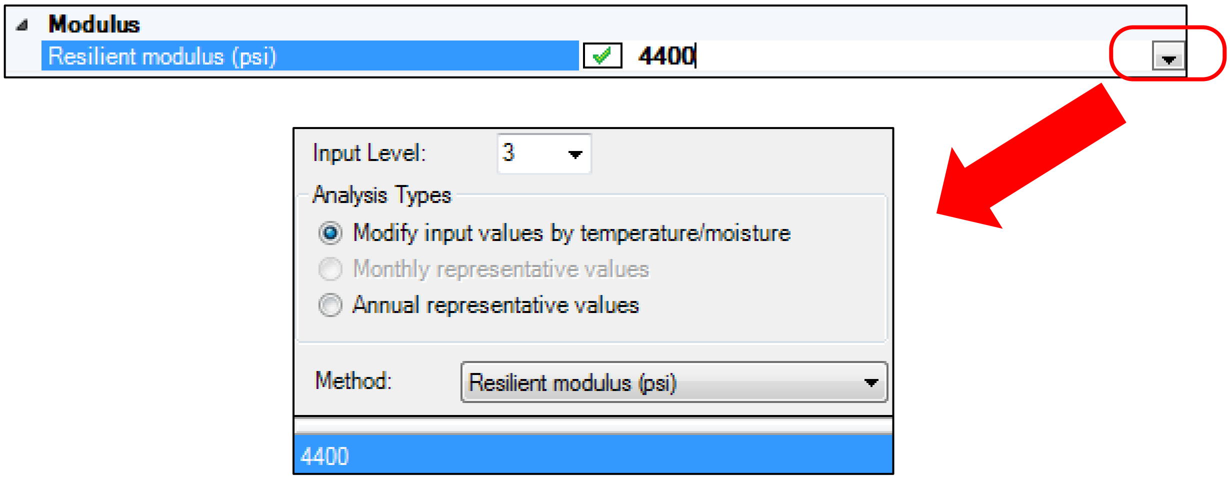



**Figure 12-3. Modulus Inputs**

Input Level

Level 1 is not available as a choice. Levels 2 and 3 are identical except that with level 2, there are additional choices available for the 'Analysis Type' and 'Method' inputs. These additional choices (noted below) will not be utilized so levels 2 and 3 essentially become the same. The designer may choose either level.

Analysis Types

This input tells the software whether the Enhanced Integrated Climatic Model (EICM) will be utilized on this layer. For level 3, there are two choices: "Modify Inputs By Temperature/Moisture" (which uses the EICM) or "Annual Representative Value" (which does not use the EICM). Level 2 adds one more choice: "Monthly Representative Values", which does not use the EICM. Since MDOT research was based on annual representative estimations, select the "Annual representative values" option for either level.

Method

With this input, other properties can be entered that will then be converted to resilient modulus using correlations internal to the software. For level 3, only resilient modulus is available as a choice. Level 2 has the following choices:

- Resilient Modulus
- California Bearing Ratio (CBR)
- R-value
- Layer coefficient – ai
- Dynamic Cone Penetrometer (DCP) penetration
- Plasticity Index and Gradation (which are entered in the 'Gradation & Other Engineering Properties' area – see Section 12.2.3 – Gradation & Other Engineering Properties)

Choose resilient modulus for this input for either level.

Value

The resilient modulus of the different subgrade soil types was determined as part of the research project *Pavement Subgrade MR Design Values for Michigan's Seasonal Changes* (Report RC-1531). The recommended values from that project can be found in Table 12-2. A value outside of the ranges provided in Table 12-2 may be recommended, but test verification should be available to support it. The distress outputs for asphalt designs are sensitive to this input.

**Table 12-2. Subgrade Resilient Modulus Values**

| Subgrade Soil Type (Unified Classification) | Resilient Modulus, psi |
|---|---|
| Lean Clay (CL) | 3700–5100 |
| Silt (ML) | 3700–5100 |
| Clayey Sand (SC) | 3700–5100 |
| Clayey Sand – Silty Sand (SC-SM) | 4200–5800 |
| Silty Sand (SM) | 4400–6000 |
| Poorly Graded Sand (SP) | 5500–7500 |
| Poorly Graded Sand – Silty Sand (SP-SM) | 5900–8100 |

### 11.2.3 – Gradation & Other Engineering Properties

This area contains several other layer property inputs as seen in Figure 12-4. To access this area, click in the box containing the AASHTO classification to obtain the drop-down arrow, and then click the arrow.

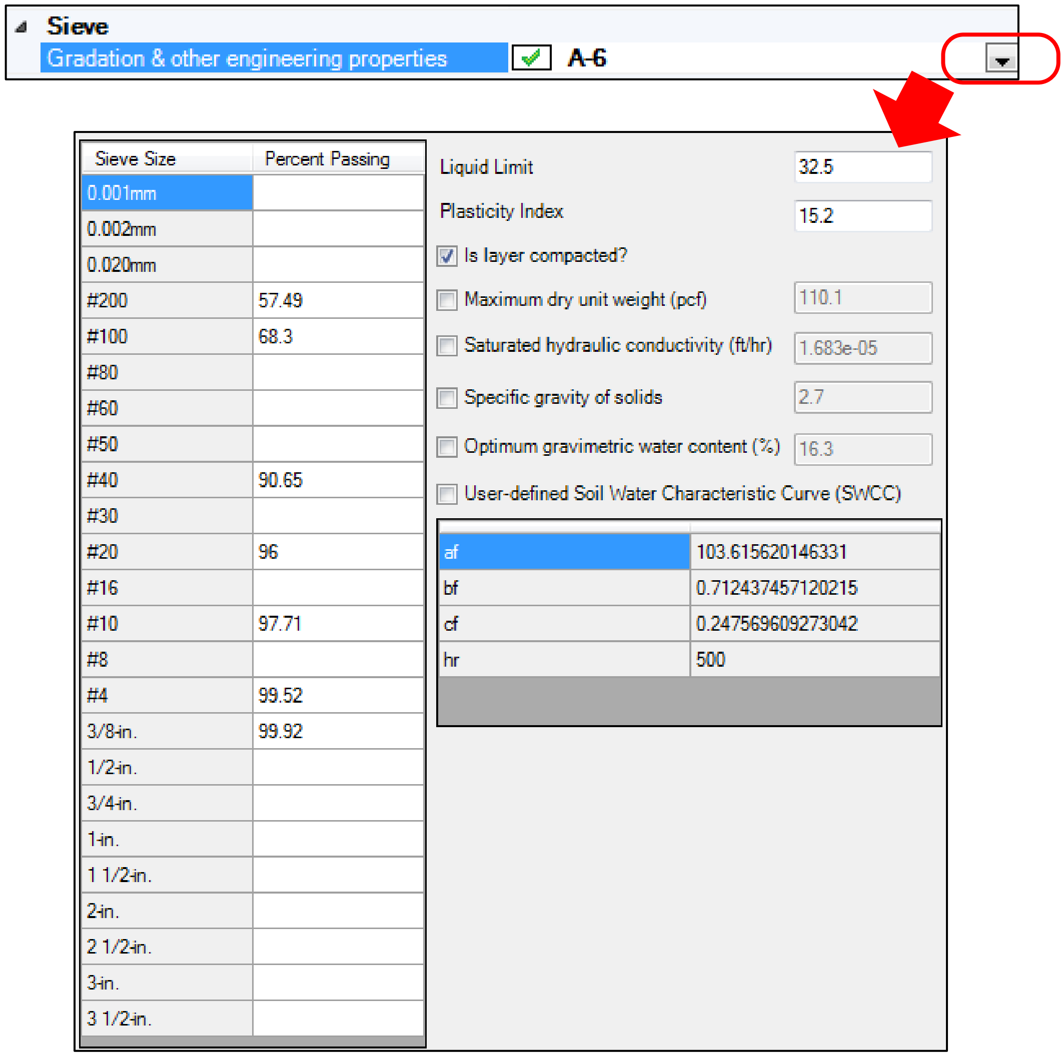



**Figure 12-4. Gradation and Other Properties Input Box**

Sieve

The percent passing various sieve sizes is to be entered. All the typical sieve sizes from 3.5" down to 0.001 mm are available, however, only a minimum of three need be entered. Table 12-3 contains the gradations to be used for each of the subgrade types. The distress outputs are sensitive to this input.

**Table 12-3. Subgrade Soil Gradations**

| Sieve | CL | ML | SC | SC-SM | SM | SP | SP-SM |
|---|---|---|---|---|---|---|---|
| 3/8" | 99.9 | 100 | 99.7 | 99.9 | 99.9 | 98.2 | 96.3 |
| No. 4 | 99.5 | 99.4 | 98.5 | 98.6 | 98.6 | 96.2 | 92.5 |
| No. 10 | 97.7 | 98.0 | 94.2 | 94.0 | 94.2 | 93.7 | 87.2 |
| No. 20 | 96.0 | 93.4 | 91.2 | 84.2 | 88.8 | 89.7 | 79.4 |
| No. 40 | 90.7 | 83.2 | 82.2 | 69.2 | 73.3 | 75.2 | 66.1 |
| No. 100 | 68.3 | 64.5 | 53.5 | 38.8 | 37.4 | 9.0 | 17.5 |
| No. 200 | 57.5 | 55.1 | 40.9 | 29.9 | 26.7 | 2.5 | 6.6 |

Liquid Limit

The liquid limit of the subgrade is to be entered. The values for each of the subgrade soil types can be found in Table 12-4. The distress outputs for asphalt designs are sensitive to this input.

**Table 12-4. Subgrade Liquid Limit Values**

| Subgrade Soil Type | Liquid Limit |
|---|---|
| CL | 32.5 |
| ML | 21.0 |
| SC | 32.8 |
| SC-SM | 17.7 |
| SM | 17.0 |
| SP | 0 |
| SP-SM | 15.5 |

Plasticity Index

Plasticity Index is the difference between the liquid limit and the plastic limit. The values for each of the subgrade soil types can be found in Table 12-5. The distress outputs are sensitive to this input.

**Table 12-5. Subgrade Plasticity Index Values**

| Subgrade Soil Type | Plasticity Index |
|---|---|
| CL | 15.2 |
| ML | 21.0 |
| SC | 17.2 |
| SC-SM | 5.6 |
| SM | 3.0 |
| SP | 0 |
| SP-SM | 5.0 |

Is Layer Compacted?

MDOT requires the subgrade to be compacted to a certain density, so check the box for this input to indicate that it is compacted.

Maximum Dry Unit Weight

This is the unit weight of the material at its maximum density (zero air voids). The values for each of the subgrade types can be found in Table 12-6.

**Table 12-6. Subgrade dry unit weight values**

| Subgrade Soil Type | Max. Dry Unit Weight, lb./cu. ft. |
|---|---|
| CL | 113.5 |
| ML | 106.2 |
| SC | 110.6 |
| SC-SM | 118.8 |
| SM | 112.1 |
| SP | 110.6 |
| SP-SM | 113.8 |

<u>Saturated Hydraulic Conductivity</u>

This input is a measure of the water movement properties within a saturated granular material under a hydraulic gradient. Leave the box unchecked to allow the software to calculate this value based on other entered properties.

<u>Specific Gravity of Solids</u>

This input is the ratio of the density of the solids portion of the material (i.e. minus the water) to that of water. Leave the box unchecked to allow the software to calculate this value based on other entered properties.

<u>Optimum Gravimetric Water Content</u>

This input is the water content (by weight) that produces the maximum unit weight for the material. Leave the box unchecked to allow the software to calculate this value based on other entered properties.

<u>User-Defined Soil Water Characteristic Curve</u>

The soil water characteristic curve is the relationship between the material's water content and its suction properties. The user can enter the values for the four coefficients required for the curve. Leave the box unchecked to allow the software to calculate the coefficients based on other entered properties.

# Chapter 13 – Existing Layer Inputs for Rehabilitation Design

## 13.1 – Introduction

*Intentionally Left Blank (To be included in a future edition)*

# Chapter 14 – Assessing the Results/Modifying the Design

## 14.1 – Output Files

When Pavement ME Design has completed the design analysis, a report will be generated in PDF format and will be opened for review. If the Excel output option is set to 'True' in the Tools menu (see Section 2.6.2.7 – Other Nodes), a Microsoft Excel report will also be generated but will not be immediately displayed. Examples of the PDF report for a new/reconstruct asphalt and concrete design can be found in APPENDIX C.

The PDF and Excel (if generated) reports are saved in the results folder that Pavement ME Design creates when the analysis is started. This results folder will be in the same location as where the design file is saved, and the report files will have the same name as the design file. Table 14-1 shows an example how the report filenames are generated and where they are saved.

**Table 14-1. Example Report File Names and Location**

| | Filename | Save Location |
|---|---|---|
| **Design File** | M-99 Concrete.dgpx | C:\ME Designs\M-99 |
| **Report Files** | M-99 Concrete.pdf<br>M-99 Concrete.xls | C:\ME Designs\M-99\M-99 Concrete |

In the above example, the user has created a folder on their hard drive called "ME Designs" to store their designs in. The user has also created a subfolder called "M-99" in the "ME Designs" folder to store their M-99 designs. The design file has been called "M-99 Concrete" and stored in the "M-99" subfolder. The design file can be stored in any location of the user's choosing – it does not have to go in the default folder as defined in the Tools menu (see Section 2.6.2.7 – Other Nodes).
Upon successful analysis, the report files will be called "M-99 Concrete" to match the design filename. The report files can be opened directly from the results folder. Alternatively, if the project is open in Pavement ME Design, the report files can be opened from location in the Explorer Pane shown in Figure 14-1.

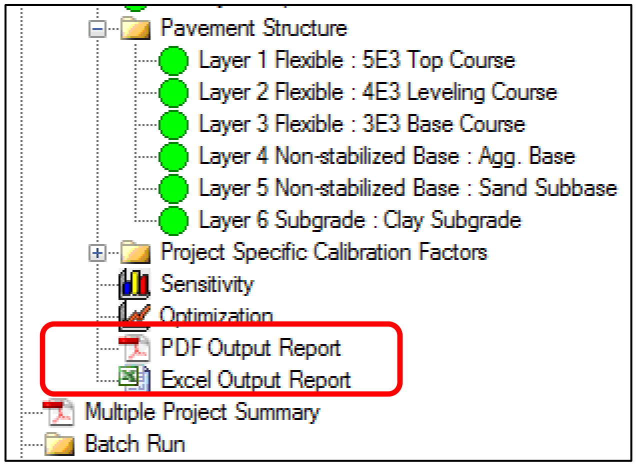



**Figure 14-1. Location of Report Files for a Successful Analysis**

Double-clicking either of the report nodes shown in Figure 14-1, will open the respective report file. If the report was not created after a successful analysis (as noted by a report generation error message), double-clicking the report node will cause Pavement ME Design to attempt to regenerate the report. A summary report of all successfully run projects that are currently open can be generated. To do this, double click the 'Multiple Project Summary' node in the Explorer Pane (just below the highlighted box in Figure 14-1). This will generate a single PDF report containing the first page from each individual project's PDF report.

When using Batch Mode, the PDF report files will not automatically be displayed at the completion of the analysis. To view the report file for any of the designs, double click the filename while the project is still loaded in the Batch Run folder. In addition, a summary report for all projects currently open in the Batch Run folder can be generated by right clicking the Batch Run node and selecting 'View Batch Report' as shown in Figure 14-2. The summary report will be a single PDF file containing the first page from each individual project's PDF report.

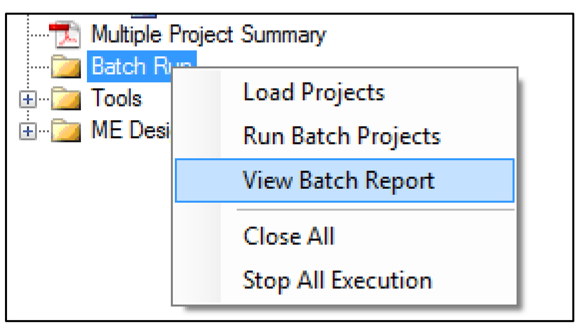



**Figure 14-2. Method for Obtaining a Batch Run Summary Report**

### 14.2 – Reviewing the Output

The report files (both PDF and Excel versions) contain summaries of the inputs and predicted results (distresses and reliabilities). The assessment of the adequacy of the design begins with a review of the report file.

### 14.2.1 –PDF Report

The PDF report is divided into several sections as follows:

- Design Inputs: A summary of the design inputs (design type, design life, month/year of expected construction, and climate file latitude/longitude), a summary of the entered cross-section, and trucks expected over the design life.
- Design Outputs: A summary of distresses predicted at the end of the design life, reliability achieved, and graphs of the predicted distresses.
- Traffic inputs summary : Graphical and tabular representation of the traffic inputs
- Climate input summary: Weather station(s) used, latitude/longitude, annual weather statistics, and graphical representation of the monthly weather values over the design life
- Design properties: Summary of the inputs from the Design Properties node inputs
- Thermal cracking inputs (asphalt designs only): Summary of the inputs used in the thermal cracking model
- Asphalt dynamic modulus summary (asphalt designs only): Charts of the dynamic modulus master, shift and viscosity curves for each asphalt layer
- Analysis output: Graphs of the performance criteria predictions over the entire design life
- Layer modulus values: Graphs of the modulus variation for each layer over the design life
- Layer information: Summary of the inputs for each layer
- Calibration coefficients: Summary of the calibration coefficients used for the analysis

Each of these areas should be reviewed to verify that the inputs entered were correct and that reasonable values for things such as truck traffic, temperatures, modulus values, etc., are being used.

### 14.2.2 – Microsoft Excel Report

The Excel report file contains the same information as the PDF report except it is divided into separate tabs. The Excel file, however, also contains additional information:

- tables of the month-by-month distress predictions
- table of the sub-layer modulus values (asphalt designs only)
- concrete strength gain, subgrade dynamic k-value, and joint load transfer efficiencies over the design life (concrete designs only)

## 14.3 – Assessing the Design Results

After the report files have been reviewed and verified that all inputs are correct, the design results must be assessed to determine if the entered cross-section should be accepted as the final design for that project. The final predicted values for the performance criteria being used (see Tables 5-1 and 5-2), and their respective reliabilities should be reviewed for this assessment. Only the performance criteria being considered need be reviewed. Therefore, the criteria listed in Tables 5-1 and 5-2 as “do not use” can be ignored for assessing the design.

The design can be accepted when all performance criteria being used are shown in the report as passing the design threshold/reliability entered. Care must be taken in assessing the results, however. If all the criteria pass by a wide margin, then the design could be considered "over-designed" and a more economical design should be pursued. For this reason, the final design should have at least one of the performance criteria at close as possible to the design threshold. This can be achieved by continuing to make incremental changes (as allowed in Section 14.4 – Changing the Design) until one of the performance criteria fails. The design prior to the failed design would be accepted as the final design. On the other hand, if the initial design fails, the incremental changes should be made until the failed performance criteria passes. The one exception to this is the thermal cracking criteria for asphalt designs (discussed in Section 14.4.2 – Asphalt Designs). To be accepted as final, the design must meet at least one of the following:

1. At least one of the performance criteria is as close as possible to its threshold value and one incremental change in the design causes it to exceed the threshold
2. The pavement thickness is at the minimum allowed according to Table 14-2 and the performance criteria being used do not exceed their threshold value
3. All performance criteria do not exceed their threshold value and continuing with the next incremental change would cause the pavement thickness to be more than ±1" from the initial design determined according to Section 3.1.3 – Step 3: Create Initial Trial Design

**Table 14-2. Minimum Pavement Thicknesses**

| MDOT Pavement Type | Minimum Thickness |
|---|---|
| Asphalt Reconstruct | 6.5" total for 3 courses of asphalt |
| JPCP Reconstruct | Non-freeway – 8"; Freeway – 9" |
| Unbonded Concrete Overlay | 6" |
| Asphalt over Rubblized Concrete | 6.5" total for 3 courses of asphalt |
| Asphalt over Crush and Shaped Asphalt | 3.5" total for 2 courses of asphalt |
| Aggregate Lift with Asphalt Resurfacing | 6.5" total for 3 courses of asphalt |
| Multi-course asphalt overlay of intact concrete, HMA, or composite | 3.5" total for 2 courses of asphalt |

Note that if the design is concrete using a widened slab, then reduce the ME final concrete slab thickness by up to 1" for design final thickness. This reduction should not exceed MDOT minimum thickness standards or ± 1" pavement thickness from the initial design (AASHTO 1993 final).

## 14.4 – Changing the Design

If the design fails one of the performance criteria, or if the design passes all criteria without one being close to the threshold, a change must be made, and the analysis re-run. The inputs that are allowed to be changed are restricted to just a few. The following sections list what inputs can be changed.

### 14.4.1 – Concrete Designs

The concrete thickness can be changed in ½" increments up to a maximum change of ±1" from the initial design. Dowel bar diameter and joint spacing must be adjusted along with the concrete thickness according to the MDOT *Road Standard Plans* R-40 and R-43, respectively.

Note that if the design is concrete using a widened slab, then reduce the ME final concrete slab thickness by up to 1" for design final thickness. This reduction should not exceed MDOT minimum thickness standards or ± 1" pavement thickness from the initial design (AASHTO 1993 final). See Section 14.3 – Assessing the Design Results for further details.

### 14.4.2 – Asphalt Designs

Each asphalt layer can be adjusted in ¼" increments up to a maximum change in the total asphalt thickness of ±1" from the initial design. The requirements of the HMA Mixture Selection Guidelines (Section 6.03.09 of the MDOT *Road Design Manual*) must be met, including:

- Choice of mix type based on flexible equivalent single axle loads (ESAL's) estimated for the project
- Mix types that are allowed for the top, leveling, and base courses
- Minimum and maximum lift thicknesses for each mix type
- Choice of binder according to region and mix type (except for changes allowed below)

Any changes in mix type or binder require that the dynamic modulus (E*), binder modulus (G*), indirect tensile strength (IDT), and creep compliance properties be changed along with them.

Thermal Cracking

Thermal cracking gets special consideration with the changes allowed. If the thermal cracking (transverse cracking) criteria does not pass in the initial design, the low-temperature grade of the binder is adjusted down one grade:

- -22 is changed to -28
- -28 is changed to -34

The high temperature grade is not changed. Only one grade change is allowed for a design. No changes are made when the standard binder for a region/mix type has a -34 low temperature grade. The change is retained regardless of whether the thermal cracking criteria passes or fails after the change. This change overrides the guidelines for binder selection contained in the HMA Mixture Selection Guidelines (Section 6.03.09 of the MDOT *Road Design Manual*). First, make this change to all HMA layers in the design. If the thermal cracking passes, then only apply the change to the top and leveling courses. However, if this causes the thermal cracking to fail, then apply the change to all HMA layers again.

During changes in asphalt thickness if the thermal cracking changes from passing to fail, then it is treated the same as the other performance criteria (i.e. the failed distress is handled with a thickness change - no binder change is required).

## 14.5 – Final Design Verification (QA)

When the designer arrives at a final design that meets all criteria outlined in Sections 14.3 and 14.4, it will need to go through the quality assurance (QA) process. Designs (and all related information) completed by region pavement designers will be submitted to ProjectWise, within the job folder, under 'Pre-construction', under 'Pavement Design', in the 'Draft' folder. The Pavement Management Section at Construction Field Services Division will conduct the QA. When all documents are ready for QA, send an email according to the following Pavement Management Section personnel:

- Superior, North, Grand, and Southwest Regions: Jami Trudelle
- Bay, University, and Metro Regions: Justin Schenkel

The design and related information needed for QA are specified by the 'Instructions' document, found in the 'ME Pvmt Design\Submittal Forms' subfolder on the Construction Field Services Division common drive.

Results of the QA will be provided within 7 business days. Designs that do not pass QA will need to be corrected, re-run, and resubmitted for QA. QA results on resubmittals will be provided within 7 business days.

Designs completed by the Pavement Management Section will be reviewed internally, within the Pavement Management Section. In addition, the region pavement designer will be given an opportunity to review the design.

The following items should be evaluated when conducting ME design review:

- Are there any warning messages (indicated by a yellow exclamation point)? If so, are these acceptable?
- What designs were investigated before the decision was made on which to recommend as final (design iterations)? What was the output from those designs? Is there a better option?
- Verify that correct designations of pavement/fix type have been chosen.
- Verify that the correct design life has been chosen.
- Verify that default items have not been changed.
- Verify that inputs that have been changed are appropriate and acceptable.
    - Traffic Data
    - Climate Data
    - Thickness of pavement layers
    - Pavement characteristics that are allowed to be varied (joint spacing, dowel bar diameter, etc.)
    - Materials inputs that are allowed to be varied
- Verify asphalt layer property inputs.
- Examine outputs to verify that the final recommended design is appropriate and acceptable.
- Verify that all other pavement design standards (minimum thicknesses, HMA lift thicknesses, base/subbase, etc.) have been followed.

## 14.6 – Report Final Design

Once the design has been accepted through the QA process, it can move on to the next stage. Provide the final design cross-section and other pertinent pavement information (binder selection, joint spacing, etc.) to the Project Manager for incorporation into the project plans.

# REFERENCES


1. NCHRP Project 1-37A, "Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures," Final NCHRP Report, 2004.

2. AASHTO, “AASHTO Guide for Design of Pavement Structures”, American Association of State Highway and Transportation Officials, 1993.

3. *DARWin Version 3.1.010*, American Association of State Highway and Transportation Officials, 2004.

4. AASHTO, "Mechanistic-Empirical Pavement Design Guide: A Manual of Practice: Interim Edition," American Association of State Highway and Transportation Officials, 2008.

5. AASHTO, "Mechanistic-Empirical Pavement Design Guide: A Manual of Practice: Second Edition," American Association of State Highway and Transportation Officials, 2015.

6. AASHTO, "Mechanistic-Empirical Pavement Design Guide: A Manual of Practice: Third Edition," American Association of State Highway and Transportation Officials, 2020.

7. *AASHTOWare Pavement ME Design Version 2.3*, American Association of State Highway and Transportation Officials, 2016.

# APPENDICES

## APPENDIX A – DARWin Inputs (AASHTO 1993 Method)

This appendix provides standards and inputs for MDOT pavement design using the *1993 AASHTO Guide for Design of Pavement Structures* and the AASHTO pavement design software DARWin Version 3.1, 2004.

Typical design lives (used to calculate total ESAL) are noted in the following table.

| Pavement Fix | Design Life (Years) |
|---|---|
| New/Reconstructed Concrete or HMA Pavements | 20 |
| HMA over Rubblized Concrete | 20 |
| Unbonded Concrete Overlay (6-inches or more) | 20 |
| Thin Concrete Overlay (less than 6-inches) | 15 |
| Concrete or HMA on Aggregate Grade Lift | 20 |
| HMA over Crush & Shaped HMA | 15 or 20 |
| Multicourse HMA over Asphalt Stabilized Crack Relief Layer (ASCRL) Overlay | 20 |
| Multicourse HMA Overlay | 15 or 20 |

The AASHTO 1993 pavement design procedure uses several inputs to determine a proper pavement design. Values to use are identified in the following sections.

### APPENDIX A.1 – All Pavement Types

1) Initial Serviceability - 4.5
2) Terminal Serviceability - 2.5
3) Reliability Level - 95%
4) Subgrade Resilient Modulus - Typical Range: 3000 – 5500 psi
   a. There are generally two methods for determining the resilient modulus of the subgrade:
      i. Back-calculation from FWD data.
         1. Contact Construction Field Services Division to schedule FWD testing.
      ii. Soil identification.
         1. After visual identification of the soil type from hand augering or soil borings, a resilient modulus can be assigned based on historical correlations.
5) Layer Thickness - The following thicknesses are typical values that may be subject to change depending on unique conditions.

| Layer | Thickness (inches) |
|---|---|
| HMA Top Course | 1.5 – 2.5 |
| HMA Leveling Course | 2 – 3.75 |
| HMA Base Course | 3 – 5 |
| ASCRL | 3 – 5 |
| Cement Stabilized Base | 4 – 6 |
| Asphalt/Emulsion Stabilized Base | 4 – 6 |
| Dense-Graded Aggregate Base | 6 |
| Open-Graded Drainage Course | 6, (except for Metro Section, use 16) |
| Sand Subbase | Per the reconstruction type:<br>• HMA design: 18, (except for Metro Region use 8)<br>• Concrete design: 10, (except for Metro Region use 0) |
| Crush & Shaped HMA*† | Thickness of existing HMA plus 1" of existing aggregate base |
| Rubblized Concrete* | Thickness of existing PCC thickness |
| Existing PCC* | Thickness of existing PCC thickness |
| Existing HMA* | Thickness of existing HMA (before milling) |
| HMA Cold Milling | Planned cold milling thickness (average) |
| Existing Aggregate Base* | Per the fix type:<br>• Crush & Shape: Thickness of the existing aggregate base minus 1"<br>• All others: Thickness of the existing aggregate base |
| Existing Sand Subbase* | Thickness of the existing sand subbase |

** Existing thicknesses for each layer should be determined by coring, FWD/GPR, and/or historical reference. Note that if using historical reference that intermixing or construction variability may cause the thickness to be different than what was designed for in past plans. Use predominant or average thicknesses.*

*† For crush & shape projects, the existing HMA thickness should not be overly thick, (greater than 6"). If so, milling should be conducted before crushing, so that the HMA can be fully crushed and densified.*

## APPENDIX A.2 – HMA Pavements

This section applies to designs for HMA reconstruction, HMA over crush and shaped HMA, HMA over existing HMA, and HMA over rubblized concrete. The following table lists the recommended DARWin 3.1 modules and analysis/evaluation type per design fix type.

| | DARWin 3.1 | |
|---|---|---|
| **Pavement Fix** | **Module** | **Analysis/ Evaluation Type** |
| HMA reconstruction | Flexible Structural Design | Specified or Layered |
| HMA over crush and shaped HMA | Flexible Structural Design | Specified |
| HMA over existing HMA | Overlay Design – AC Overlay of AC Pavement | Component (Specified) |
| HMA over rubblized concrete | Flexible Structural Design | Specified or Layered |

1) Overall Standard Deviation - 0.49

2) Structural Layer Coefficients - These coefficients ($a_i$ values) convert corresponding layer thicknesses to structural number which is the measure of the relative structural component of the pavement section. As such, it is correlated to the elastic (resilient) modulus (strength characteristic) of the layer and the position (depth) of the layer in which the material will be used within the pavement cross-section. Per AASHTO guidance (*AASHTO Guide for Design of Pavement Structures, Part II, Section 2.3.5*) and MDOT practices, the following table lists the recommended structural coefficients per layer.

| **Layer** | | **Str. Coef.** |
|---|---|---|
| HMA Top & Leveling Course | | 0.42 |
| HMA Base Course | | 0.36 |
| ASCRL | | 0.30 |
| Cement Stabilized Base | | 0.26 |
| Asphalt/Emulsion Stabilized Base | | 0.22 |
| Crush & Shaped HMA | | 0.20 |
| Rubblized Concrete | | 0.18 |
| Dense-Graded Aggregate Base | | 0.14 |
| Open-Graded Drainage Course | | 0.13 |
| Sand Subbase | | 0.10 |
| Existing HMA** | Excellent condition –<br>• little or no alligator cracking and/or low-severity transverse cracking | 0.36 |
| | Good condition –<br>• < 10% low-severity alligator cracking and/or<br>• < 5% medium and high-severity transverse cracking | 0.30 |
| | Fair condition –<br>• > 10% low-severity alligator cracking and/or<br>• < 10% medium-severity alligator cracking and/or<br>• 5-10% medium and high-severity transverse cracking | 0.24 |
| | Poor condition –<br>• > 10% medium-severity alligator cracking and/or<br>• < 10% high-severity alligator cracking and/or<br>• > 10% medium and high-severity transverse cracking | 0.17 |
| | Very poor condition –<br>• > 10% high-severity alligator cracking and/or<br>• > 10% high-severity transverse cracking | 0.12 |
| Existing Aggregate Base | No evidence of pumping*, degradation, or contamination by fines | 0.13 |
| | Evidence of pumping*, degradation, or contamination by fines | 0.06 |
| Existing Sand Subbase | No evidence of pumping*, degradation, or contamination by fines | 0.09 |
| | Evidence of pumping*, degradation, or contamination by fines | 0.04 |

** Note that pumping may be observed by water or fine sands bleeding up through cracks in the surface pavement. Faulting may also be present.*

*** The existing HMA can be represented by multiple layers, but one layer is sufficient. The existing HMA structural coefficient should represent the material present after milling or repair(s), (to be overlaid).*

3) Elastic Modulus - This is a measure of the layer's stiffness as its resistance to being deformed elastically (non-permanently) when a stress (load) is applied, expressed as the stress divided by strain. As previously noted, the elastic modulus is used to estimate structural coefficient. Moreover, it can be used for AASHTO layered design analysis (*AASHTO Guide for Design of Pavement Structures, Part II, Section 3.1.5*) to solve for the thickness of layers to achieve the design structural number. Per AASHTO guidance and MDOT practices, the following table lists the recommended elastic modulus values per layer.

| **Layer** | **Elastic Modulus (psi)** |
|---|---|
| HMA Top & Leveling Course | 390,000 – 410,000 |
| HMA Base Course | 275,000 – 320 000 |
| ASCRL | 210,000 |
| Cement Stabilized Base | 1,000,000 |
| Asphalt/Emulsion Stabilized Base | 160,000 |
| Crush & Shaped HMA | 100,000 – 150,000 |
| Rubblized Concrete | 45,000 – 55,000 |
| Dense-Graded Aggregate Base | 30,000 |
| Open-Graded Drainage Course | 24,000 |
| Sand Subbase | 13,500 |
| Existing Aggregate Base | 15,000** – 28,000* |
| Existing Sand Subbase | 7,500** – 12,500* |

** No evidence of pumping, degradation, or contamination by fines*

*** Evidence of pumping, degradation, or contamination by fines*

4) Drainage Coefficient - This coefficient ($m_i$ values) impacts the layer's relative strength due to drainage characteristics and exposure to moisture saturation. A drainage coefficient of 1 indicates typical drainage characteristics for that layer. Values less than 1 would reflect moisture problems and values greater than 1 reflect improved drainage characteristics. Per AASHTO guidance (*see Table 2.4, page II-25, AASHTO Guide for Design of Pavement Structures*) and MDOT practices, the following table lists the recommended drainage coefficient per layer.

| **Layer** | **Drainage Coefficient** |
|---|---|
| HMA Top & Leveling Course | 1 |
| HMA Base Course | 1 |
| ASCRL | 1 |
| Cement Stabilized Base | 1.1 |
| Asphalt/Emulsion Stabilized Base | 1 |
| Crush & Shaped HMA | 1 |
| Rubblized Concrete | 1 |
| Aggregate Base (Dense and Open) | 1 |
| Sand Subbase | 1 |
| 16-inches of Open-Graded Drainage Course | 1.1 |
| < 16-inches of Open-Graded Drainage Course | 1 – 1.05 |
| Existing HMA | 1* |
| Existing Aggregate Base | 1* |
| Existing Sand Subbase | 1* |

** Use a drainage coefficient of 1 for each base/subbase layer unless there are known moisture problems in these layer(s). If so, see Table 2.4, page II-25 of the AASHTO Guide for Design of Pavement Structures 1993.*

5) Stage Construction - 1
6) HMA Overlay Total Thickness - To determine actual thickness of the HMA, divide the 'Overlay Structural Number' by 0.42

**APPENDIX A.3 – Concrete Pavements**

This section applies to designs for JPCP reconstruction, HMA over existing concrete/composite, HMA ASCRL over existing concrete/composite, and standard concrete overlays (6-inches thick or more) over existing concrete/composite. The following table lists the recommended DARWin 3.1 modules and analysis/evaluation type per design fix type.

| | DARWin 3.1 | |
|---|---|---|
| **Pavement Fix** | **Module** | **Analysis/ Evaluation Type** |
| JPCP reconstruction | Rigid Structural Design | N/A |
| HMA or HMA ASCRL over existing concrete | Overlay Design – AC Overlay of PCC Pavement | Condition Survey |
| HMA or HMA ASCRL over existing composite | Overlay Design – AC Overlay of AC/PCC Pavement | Condition Survey |
| Concrete overlays (6-inches thick or more) over concrete/composite | Overlay Design – Unbonded PCC Overlay of PCC or AC/PCC Pavement | Condition Survey |

1) 28-day mean PCC Modulus of rupture - 670 psi
2) 28-day mean Elastic Modulus of Slab - 4,200,000 psi
3) Mean Effective k-value (psi/in) - (see *Fig. 3.3 & 3.6, AASHTO Guide for Design of Pavement Structures*)
   a. Use AASHTO's chart for "Estimating Composite Modulus of Subgrade Reaction" and "Correction of Effective Modulus of Subgrade Reaction for Potential Loss of Subbase Support":
      i. Typical Range: 100 – 200 psi/in
      ii. The term "subbase" used in Figure 3.3 is considered a composite of all base/subbase materials under the concrete. Use the weighted average of modulus values listed above in the HMA Pavement inputs (Appendix A.2). For standard base/subbase combination, use 20,000 psi.
4) Overall Standard Deviation - 0.39

5) <u>Load Transfer Coefficient, J</u> -

| Shoulder/Slab Configuration | Load Transfer Coefficient |
|---|---|
| Tied Shoulder or widened slab (14-ft) | 2.7 |
| Untied Shoulders | 3.2 |

6) <u>Overall Drainage Coefficient</u> -

| Cross-Section | Drainage Coefficient |
|---|---|
| Typical Cross-Section & Subgrade | 1 – 1.05* |
| 16-inches of Open-Graded Drainage Course | 1.1 |

** Consider the overall drainage of the system including subgrade when assigning this input.*

7) <u>Effective Existing Pavement Thickness</u> - The Condition Survey Method in the DARWin software is used to characterize the effective structural capacity of the existing pavement. Existing pavement adjustment factors are used to adjust the effective structural capacity. The following describes the adjustment factors and their associated pavement condition. Note that for ASCRL overlays, use the same steps as though it were a standard “AC Overlay of PCC Pavement,” not using ASCRL. Therefore, when designing, use the same Joints/Cracks Adjustment Factor that would be used for standard “AC Overlay of PCC Pavement” even though less repairs will actually be conducted for the ASCRL. This assumption is made because the ASCRL pavement will not be as impacted by unrepaired joints or cracks.

   a. Concrete/Composite Durability Adjustment Factor (Fdur)

      i. This accounts for **existing concrete** durability problems, such as “D” cracking or reactive aggregate distress. Past MDOT experience suggests that this distress type is typically low. Use the following values per the condition of the existing concrete pavement (per surface visual inspection, coring, FWD, and/or historical reference):

| Existing Pavement Condition | Fdur |
|---|---|
| No evidence or history of PCC durability problems | 1.0 |
| Durability cracking exists or is suspected, but no spalling due to “D” cracking or localized failures are visible | 0.98 |
| Substantial durability cracking and some spalling due to “D” cracking with visible localized failures | 0.92 |
| Extensive durability cracking and severe spalling due to “D” cracking with visible localized failures | 0.85 |

   b. Concrete Fatigue Damage Adjustment Factor (Ffat)

      i. This accounts for fatigue damage in the **existing concrete** slab. Use the following values per the condition of the existing concrete pavement:

| **Existing Pavement Condition** | **Ffat** |
|---|---|
| Few transverse cracks/punchouts exist (none caused by “D” cracking):<br>• JPCP: < 5% slabs cracked<br>• JRCP: < 25 cracks/mi (working cracks)<br>• CRCP: < 4 punchouts/mi | 1.0 |
| Significant number of transverse cracks/punchouts exist:<br>• JPCP: 5-15% slabs cracked<br>• JRCP: 25-75 cracks/mi (working cracks)<br>• CRCP: 4-12 punchouts/mi | 0.96 |
| Several transverse cracks/punchouts exist:<br>• JPCP: > 15% slabs cracked<br>• JRCP: > 75 cracks/mi (working cracks)<br>• CRCP: > 12 punchouts/mi | 0.93 |

c. Joints and Cracks Adjustment Factor

i. This accounts for all unrepaired deteriorated joints and cracks that are not durability (“D” cracking) related in the **existing concrete** or **composite** (HMA over concrete) pavement. This is calculated per the sum of all unrepaired deteriorated joints, cracks, punchouts, expansion joints, wide joints (>1”), and HMA full depth patches per lane-mile. If all of these are repaired with concrete patches prior to the overlay, then the sum is 0 and the calculated factor is 1.0. The max allowable summation is 200. Pavements worse than this should be repaired, so that the sum is 200 or less. Note that for ASCRL overlays, use the same Joints/Cracks Adjustment Factor that would be used for standard HMA overlays even though less repairs will actually be conducted for the ASCRL. This assumption is made because the ASCRL pavement will not be as impacted by unrepaired joints or cracks. Past MDOT experience suggests the following typical ranges for overlay projects, but actual values may vary based on the condition survey and project scope:

| **Unrepaired Condition** | **Typical Number per Mile** |
|---|---|
| Unrepaired deteriorated joints* | 20 – 40 |
| Unrepaired deteriorated cracks | 20 – 40 |
| Unrepaired punchouts** | 5 – 10 |
| Expansion joints, wide joints (>1”), or HMA full depth patches | 5 – 10 |

** Not needed if HMA overlay of existing composite pavement*

***While punchouts are commonly associated with CRCP, it is possible to have them in JPCP/JRCP.*

d. HMA AC Quality Adjustment Factor (Fac)

i. This accounts for defects and/or deformation in the **existing HMA** pavement that are not or cannot be eliminated by surface milling. Use the following values per the condition of the existing HMA pavement:

| Existing Pavement Condition | Fac |
|---|---|
| No HMA pavement material distress | 1.0 |
| Minor HMA material distress (weathering or raveling) not corrected by milling | 0.96 |
| Significant HMA material distress (rutting, stripping, and/or shoving) | 0.93 |
| Severe HMA material distress (rutting, stripping, and/or shoving) | 0.85 |

## APPENDIX A.4 – Concrete Overlays (thin over any pavement type & unbonded over existing full-depth HMA)

This section applies to designs for thin concrete overlays (less than 6-inches thick) over any existing pavement type and unbonded concrete overlays (6-inches thick or more) over full-depth HMA.

1) Thin Concrete Overlay (less than 6”) -

Use the following table to determine the concrete overlay thickness. Use the closest CADT or CESAL value. Note that the CESAL value is at 15-year design life. Also, note that if overlaying an **existing concrete** pavement, a separator layer is required.

| Design Lane CADT | CADT (2-way) | CESAL | Overlay Thickness on Existing PCC (inches) | | | | Overlay Thickness on Existing HMA (inches) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0.80 | 0.75 | 0.70 | 0.65 | 0.42 | 0.38 | 0.34 | 0.30 | ← C-factor |
| 100 | ≤ 220 | 650,000 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4.5 | |
| 150 | 330 | 970,000 | 4 | 4 | 4 | 4 | 4 | 4.5 | 4.5 | 5 | |
| 200 | 440 | 1,300,000 | 4 | 4 | 4 | 4 | 4.5 | 5 | 5 | 5.5 | |
| 250 | 550 | 1,630,000 | 4 | 4 | 4 | 4 | 5 | 5.5 | 5.5 | | |
| 300 | 650 | 1,950,000 | 4 | 4 | 4 | 4 | 5.5 | 5.5 | | | |
| 350 | 760 | 2,270,000 | 4 | 4 | 4 | 4 | 5.5 | | | | |
| 400 | 870 | 2,590,000 | 4 | 4 | 4 | 4.5 | | | | | |
| 450 | 980 | 2,900,000 | 4 | 4 | 4.5 | 5 | | | | | |
| 500 | 1090 | 3,230,000 | 4 | 4.5 | 4.5 | 5 | | | | | |
| 600 | 1310 | 3,900,000 | 4.5 | 5 | 5 | 5.5 | | | | | |
| 700 | 1525 | 4,500,000 | 5 | 5 | 5.5 | | | | | | |
| 800 | 1750 | 5,200,000 | 5 | 5.5 | | | | | | | |
| 900 | 1950 | 5,800,000 | 5.5 | | | | | | | | |
| 1000 | 2000 | 6,450,000 | 5.5 | | | | | | | | |

NOTES:

- This table is derived per the Corps of Engineers (COE) Design Method empirical equation:

- $D_{OL} = \sqrt{D_N{}^2 - C(D_E)^2}$
  - $D_{OL}$ = required PCC overlay thickness (inches)
  - $D_N$ = required new PCC pavement thickness to carry future traffic (inches)
  - $D_E$ = thickness of existing pavement (inches)
  - C = coefficient depending on the structural condition of the existing pavement
    - Note that this equation does not directly apply to overlay of existing asphalt pavements, so the C-factor was adjusted to imitate existing asphalt pavement.

- Overlay ($D_{OL}$) and required new PCC pavement thickness ($D_N$) are derived using the AASHTO 1993 design method.
- Assumptions:
  - DD = 51%, DL = 90%, TF = 1.1, GR = 1%, Design Life = 15 years, 8” existing PCC, $K_{LS}$ = 150 pci
    - Note that the 8” of existing PCC is assumed for overlay of existing PCC and HMA for modeling purposes.
  - Minimum thickness of the PCC overlay is 4”.
  - The minimum remaining existing HMA and PCC thicknesses after milling or grinding is approximately 3” and 6”, respectively. If the existing pavement is composite, then the PCC minimum thickness would apply, (not the HMA minimum thickness).
- For the C-factor, use the following values per the condition of the existing pavement (per surface visual inspection, coring, FWD, and/or historical reference):
  - For overlay on **existing concrete (or composite)**, use the following values per the condition of the existing pavement:

| **Existing Pavement Condition** | **C-factor** |
|---|---|
| In fair overall structural condition with minimal cracking | 0.75 – 0.80 |
| Has mid-slab and “D” cracking, but load transfer is adequate | 0.65 – 0.70 |

  - For overlay on **existing HMA**, use the following values per the condition of the existing pavement:

| **Existing Pavement Condition** | **C-factor** |
|---|---|
| In fair overall structural condition with uniform support.<br>• Alligator cracking, transverse cracking, and rutting (after milling) are minimal. | 0.38 – 0.42 |
| Has adequate structural condition.<br>• Alligator cracking and high-severity transverse cracking are minimal.<br>• Rutting (after milling) is greater than 0.1”. | 0.30 – 0.34 |

2) Concrete Overlay (6” or more) -

MDOT will continue to use the AASHTO 1993 design method (with inputs as previously noted) for design of concrete overlay thickness of existing concrete pavement. However, for concrete overlay of **existing HMA** pavement, use the following table to determine the concrete overlay thickness. Use the closest CADT or CESAL value. Note that the CESAL value is at 20-year design life.

| Design Lane CADT | CADT (2-way) | CESAL | Overlay Thickness on Existing HMA (inches) | | | | |
|---|---|---|---|---|---|---|---|
| | | | 0.42 | 0.38 | 0.34 | 0.30 | ← C-factor |
| 250 | 550 | 2,210,000 | | | | 6 | |
| 300 | 650 | 2,650,000 | | | 6 | 6 | |
| 350 | 760 | 3,090,000 | | 6 | 6 | 6.5 | |
| 400 | 870 | 3,540,000 | 6 | 6 | 6.5 | 6.5 | |
| 450 | 980 | 3,980,000 | 6 | 6.5 | 6.5 | 7 | |
| 500 | 1090 | 4,420,000 | 6.5 | 6.5 | 7 | 7 | |
| 600 | 1310 | 5,300,000 | 6.5 | 7 | 7 | 7.5 | |
| 700 | 1525 | 6,190,000 | 7 | 7.5 | 7.5 | 7.5 | |
| 800 | 1750 | 7,070,000 | 7.5 | 7.5 | 7.5 | 8 | |
| 900 | 1950 | 7,960,000 | 7.5 | 7.5 | 8 | 8 | |
| 1000 | 2000 | 8,840,000 | 7.5 | 8 | 8 | 8.5 | |
| 1100 | 2400 | 9,720,000 | 8 | 8 | 8.5 | 8.5 | |
| 1200 | 2600 | 10,610,000 | 8 | 8.5 | 8.5 | 8.5 | |
| 1400 | 3050 | 12,380,000 | 8.5 | 8.5 | 8.5 | 9 | |
| 1600 | 3500 | 14,150,000 | 8.5 | 9 | 9 | 9 | |
| 1800 | 3925 | 15,910,000 | 9 | 9 | 9 | 9.5 | |
| 2000 | 4350 | 17,680,000 | 9 | 9 | 9.5 | 9.5 | |
| 2500 | 5450 | 22,100,000 | 9.5 | 9.5 | 10 | 10 | |
| 3000 | 6550 | 26,520,000 | 10 | 10 | 10 | 10.5 | |
| 3500 | 7625 | 30,940,000 | 10 | 10.5 | 10.5 | 10.5 | |
| 4000 | 8700 | 35,360,000 | 10.5 | 10.5 | 10.5 | 11 | |
| 4500 | 9800 | 39,780,000 | 10.5 | 11 | 11 | 11 | |
| 5000 | 10,900 | 44,200,000 | 11 | 11 | 11 | 11.5 | |
| 5500 | 12,000 | 48,620,000 | 11 | 11 | 11.5 | 11.5 | |
| 6000 | 13,075 | 53,040,000 | 11.5 | 11.5 | 11.5 | 11.5 | |

NOTES:

- This table is derived per the Corps of Engineers (COE) Design Method empirical equation:
  - $D_{OL} = \sqrt{{D_N}^2 - C(D_E)^2}$
- Overlay and required new PCC pavement thickness are derived using the AASHTO 1993 design method.

- Assumptions:
  - DD = 51%, DL = 90%, TF = 1.1, GR = 1%, Design Life = 20 years, 9" existing PCC, $K_{LS}$ = 160 pci
    - Note that the 9" of existing PCC is assumed for overlay of existing HMA for modeling purposes.
  - The minimum remaining existing HMA thicknesses after milling is approximately 3".
- For the C-factor, use the following values per the condition of the existing pavement (per surface visual inspection, coring, FWD, and/or historical reference):
  - For overlay on **existing HMA**, use the following values per the condition of the existing pavement:

| Existing Pavement Condition | C-factor |
|---|---|
| In fair overall structural condition with uniform support.<br>• Alligator cracking, transverse cracking, and rutting (after milling) are minimal. | 0.38 – 0.42 |
| Has adequate structural condition.<br>• Alligator cracking and high-severity transverse cracking are minimal.<br>• Rutting (after milling) is greater than 0.1". | 0.30 – 0.34 |

## APPENDIX B – Traffic Inputs

### APPENDIX B.1 – Vehicle Class Distribution

**Table B-1. Vehicle Class Distribution (%), Clusters and Statewide Average**

| Vehicle Class | <45 Rural | <45 Urban | 45to70 Rural | 45to70 Urban | >70 Rural | >70 Urban | NF Average | Freeway Average |
|---|---|---|---|---|---|---|---|---|
| 4 | 2.55 | 2.65 | 1.63 | 1.55 | 1.39 | 1.1 | 2.27 | 1.65 |
| 5 | 27.75 | 25.8 | 13.6 | 16.13 | 6.96 | 6.5 | 22.27 | 14.91 |
| 6 | 6.07 | 10.58 | 4.74 | 4.98 | 2.45 | 2.6 | 6.74 | 4.29 |
| 7 | 1.09 | 2.13 | 0.72 | 0.75 | 0.25 | 0.15 | 1.33 | 0.58 |
| 8 | 4.91 | 8.25 | 4.99 | 4.82 | 2.79 | 1.95 | 5.44 | 4.32 |
| 9 | 34.74 | 37.75 | 59.73 | 57.15 | 77.73 | 79 | 43.08 | 60.54 |
| 10 | 10.28 | 8.13 | 6.84 | 7.57 | 3.64 | 3.9 | 8.43 | 6.83 |
| 11 | 0.42 | 0.5 | 1.69 | 1.33 | 1.43 | 0.95 | 0.96 | 1.21 |
| 12 | 0.3 | 0.33 | 0.65 | 0.6 | 0.52 | 0.6 | 0.34 | 0.58 |
| 13 | 11.89 | 3.9 | 5.43 | 5.12 | 2.84 | 3.25 | 9.13 | 5.08 |

**NOTE:** NF is "Non-Freeway"

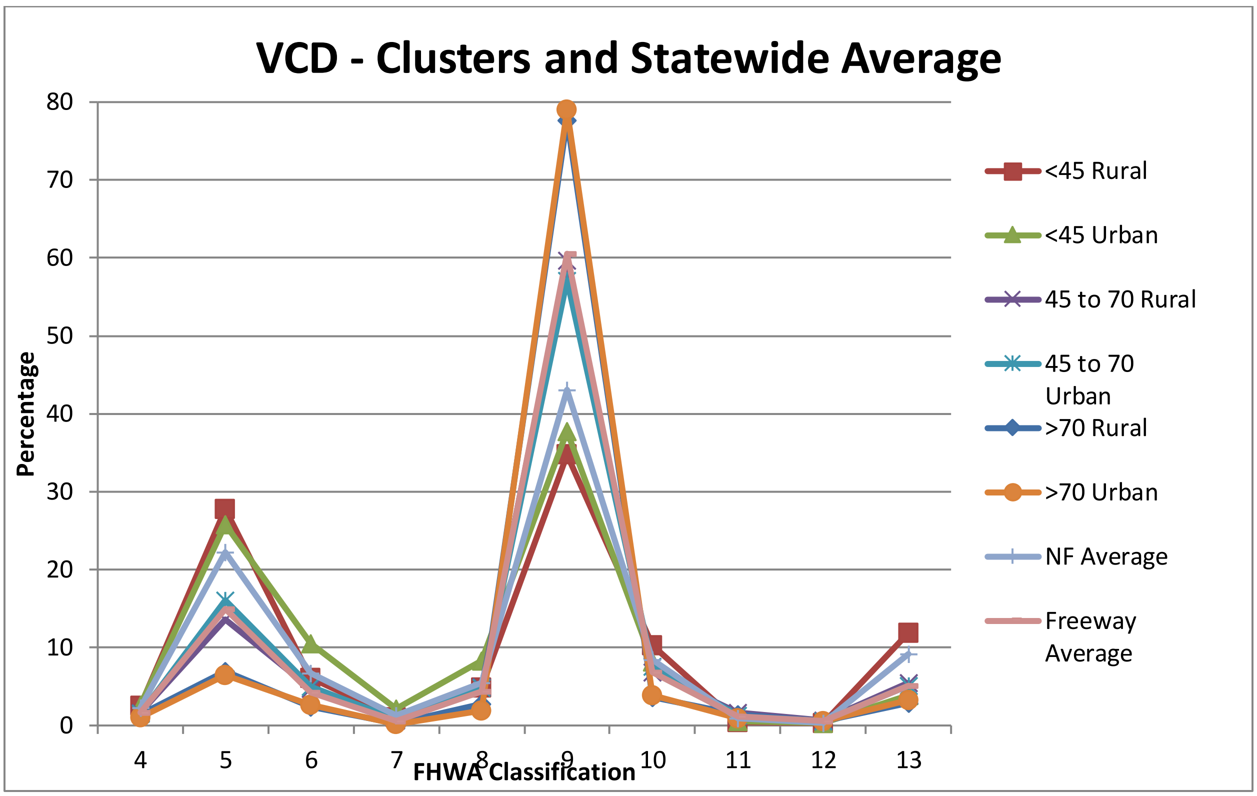



**Figure B-1. Graphical Representation of Vehicle Class Distribution (%)**

## APPENDIX B.2 – Monthly Adjustment

**Table B-2. Monthly Adjustment, <45 & Rural Cluster**

| Month | Class 4 | Class 5 | Class 6 | Class 7 | Class 8 | Class 9 | Class 10 | Class 11 | Class 12 | Class 13 |
|---|---|---|---|---|---|---|---|---|---|---|
| Jan. | 0.863 | 0.723 | 0.833 | 0.726 | 0.711 | 0.862 | 0.761 | 0.765 | 0.929 | 0.885 |
| Feb. | 0.963 | 0.752 | 0.817 | 0.717 | 0.744 | 0.933 | 0.810 | 0.859 | 0.945 | 0.913 |
| Mar. | 0.938 | 0.747 | 0.790 | 0.746 | 0.803 | 0.987 | 0.884 | 0.929 | 0.874 | 0.877 |
| Apr. | 0.934 | 0.785 | 0.871 | 0.800 | 0.892 | 1.012 | 0.907 | 0.972 | 0.962 | 0.895 |
| May. | 1.209 | 1.023 | 1.065 | 1.075 | 1.057 | 1.054 | 1.047 | 1.182 | 0.967 | 1.033 |
| Jun. | 1.076 | 1.191 | 1.158 | 1.251 | 1.216 | 1.085 | 1.183 | 1.380 | 1.010 | 1.111 |
| Jul. | 0.936 | 1.398 | 1.122 | 1.305 | 1.307 | 1.045 | 1.111 | 1.122 | 1.099 | 1.087 |
| Aug. | 0.973 | 1.418 | 1.195 | 1.200 | 1.375 | 1.095 | 1.204 | 1.099 | 1.113 | 1.145 |
| Sep. | 1.260 | 1.291 | 1.195 | 1.267 | 1.235 | 1.042 | 1.151 | 0.969 | 1.047 | 1.085 |
| Oct. | 1.211 | 1.075 | 1.142 | 1.185 | 1.058 | 1.059 | 1.204 | 0.993 | 0.976 | 1.178 |
| Nov. | 0.912 | 0.847 | 0.958 | 0.981 | 0.843 | 0.957 | 0.947 | 0.887 | 0.945 | 0.969 |
| Dec. | 0.723 | 0.750 | 0.854 | 0.746 | 0.760 | 0.867 | 0.792 | 0.843 | 1.133 | 0.821 |

**Table B-3. Monthly Adjustment, <45 & Urban Cluster**

| Month | Class 4 | Class 5 | Class 6 | Class 7 | Class 8 | Class 9 | Class 10 | Class 11 | Class 12 | Class 13 |
|---|---|---|---|---|---|---|---|---|---|---|
| Jan. | 0.943 | 0.985 | 0.838 | 0.475 | 0.883 | 0.913 | 0.718 | 0.893 | 0.605 | 0.725 |
| Feb. | 1.040 | 1.000 | 0.888 | 0.488 | 0.915 | 0.990 | 0.793 | 1.043 | 0.645 | 0.758 |
| Mar. | 1.015 | 0.923 | 0.828 | 0.658 | 0.820 | 0.978 | 0.820 | 0.945 | 0.890 | 0.773 |
| Apr. | 0.980 | 0.925 | 0.930 | 0.880 | 0.860 | 0.985 | 0.920 | 0.993 | 0.893 | 0.943 |
| May. | 1.088 | 1.030 | 1.003 | 1.095 | 1.008 | 1.003 | 1.080 | 1.265 | 1.218 | 1.113 |
| Jun. | 1.058 | 1.080 | 1.133 | 1.353 | 1.198 | 1.050 | 1.150 | 1.430 | 1.213 | 1.178 |
| Jul. | 0.928 | 1.035 | 1.113 | 1.273 | 1.210 | 1.013 | 1.123 | 0.935 | 0.920 | 1.115 |
| Aug. | 0.965 | 1.015 | 1.153 | 1.378 | 1.250 | 1.055 | 1.230 | 0.918 | 1.043 | 1.305 |
| Sep. | 0.930 | 0.973 | 1.105 | 1.353 | 1.048 | 0.995 | 1.050 | 0.815 | 1.068 | 1.090 |
| Oct. | 0.958 | 1.033 | 1.175 | 1.405 | 1.000 | 1.105 | 1.213 | 0.838 | 1.128 | 1.215 |
| Nov. | 1.088 | 0.990 | 0.980 | 1.075 | 0.918 | 0.993 | 1.043 | 0.888 | 1.265 | 1.028 |
| Dec. | 1.010 | 1.013 | 0.858 | 0.570 | 0.893 | 0.923 | 0.863 | 1.040 | 1.115 | 0.760 |

### Table B-4. Monthly Adjustment, 45 to 70 & Rural Cluster

| Month | Class 4 | Class 5 | Class 6 | Class 7 | Class 8 | Class 9 | Class 10 | Class 11 | Class 12 | Class 13 |
|---|---|---|---|---|---|---|---|---|---|---|
| Jan. | 0.796 | 0.798 | 0.816 | 0.709 | 0.817 | 0.916 | 0.838 | 0.924 | 0.825 | 0.787 |
| Feb. | 0.888 | 0.857 | 0.854 | 0.764 | 0.891 | 0.975 | 0.885 | 0.961 | 0.876 | 0.816 |
| Mar. | 0.946 | 0.908 | 0.906 | 0.836 | 0.949 | 1.024 | 0.930 | 1.037 | 0.878 | 0.881 |
| Apr. | 1.014 | 0.966 | 0.976 | 0.966 | 0.998 | 1.022 | 0.950 | 1.032 | 1.016 | 0.972 |
| May. | 1.108 | 1.073 | 1.043 | 1.084 | 1.044 | 1.005 | 1.003 | 1.003 | 0.989 | 1.065 |
| Jun. | 1.111 | 1.126 | 1.096 | 1.169 | 1.114 | 1.041 | 1.084 | 1.050 | 1.021 | 1.111 |
| Jul. | 0.968 | 1.146 | 1.067 | 1.062 | 1.091 | 0.971 | 1.034 | 0.996 | 0.943 | 1.031 |
| Aug. | 1.125 | 1.193 | 1.121 | 1.225 | 1.159 | 1.049 | 1.099 | 1.014 | 1.000 | 1.136 |
| Sep. | 1.109 | 1.118 | 1.125 | 1.259 | 1.073 | 1.048 | 1.160 | 1.026 | 1.044 | 1.124 |
| Oct. | 1.146 | 1.083 | 1.148 | 1.221 | 1.044 | 1.056 | 1.181 | 1.065 | 1.174 | 1.254 |
| Nov. | 0.977 | 0.904 | 0.971 | 0.956 | 0.935 | 0.982 | 0.975 | 0.983 | 1.023 | 1.003 |
| Dec. | 0.813 | 0.829 | 0.877 | 0.749 | 0.884 | 0.912 | 0.861 | 0.908 | 1.211 | 0.821 |

### Table B-5. Monthly Adjustment, 45 to 70 & Urban Cluster

| Month | Class 4 | Class 5 | Class 6 | Class 7 | Class 8 | Class 9 | Class 10 | Class 11 | Class 12 | Class 13 |
|---|---|---|---|---|---|---|---|---|---|---|
| Jan. | 0.826 | 0.822 | 0.831 | 0.630 | 0.838 | 0.889 | 0.806 | 0.878 | 0.854 | 0.725 |
| Feb. | 0.895 | 0.841 | 0.835 | 0.646 | 0.883 | 0.945 | 0.823 | 0.917 | 0.909 | 0.748 |
| Mar. | 0.975 | 0.904 | 0.885 | 0.797 | 0.968 | 1.021 | 0.876 | 1.019 | 1.015 | 0.791 |
| Apr. | 1.035 | 0.958 | 0.968 | 0.959 | 1.012 | 1.030 | 0.968 | 1.035 | 1.025 | 0.939 |
| May. | 1.108 | 1.041 | 1.029 | 1.122 | 1.036 | 1.011 | 1.060 | 1.009 | 0.989 | 1.077 |
| Jun. | 1.089 | 1.129 | 1.117 | 1.238 | 1.111 | 1.049 | 1.142 | 1.063 | 1.002 | 1.174 |
| Jul. | 0.947 | 1.123 | 1.087 | 1.191 | 1.066 | 0.975 | 1.091 | 1.017 | 0.968 | 1.126 |
| Aug. | 1.052 | 1.163 | 1.135 | 1.236 | 1.103 | 1.050 | 1.162 | 1.063 | 1.019 | 1.223 |
| Sep. | 1.087 | 1.101 | 1.101 | 1.183 | 1.065 | 1.043 | 1.111 | 1.041 | 1.037 | 1.171 |
| Oct. | 1.114 | 1.082 | 1.105 | 1.219 | 1.056 | 1.066 | 1.134 | 1.074 | 1.097 | 1.245 |
| Nov. | 1.029 | 0.951 | 1.007 | 1.028 | 0.958 | 1.003 | 0.984 | 0.983 | 1.069 | 1.014 |
| Dec. | 0.844 | 0.885 | 0.903 | 0.751 | 0.903 | 0.919 | 0.842 | 0.900 | 1.015 | 0.766 |

### Table B-6. Monthly Adjustment, >70 & Rural Cluster

| Month | Class 4 | Class 5 | Class 6 | Class 7 | Class 8 | Class 9 | Class 10 | Class 11 | Class 12 | Class 13 |
|---|---|---|---|---|---|---|---|---|---|---|
| Jan. | 0.771 | 0.762 | 0.836 | 0.642 | 0.828 | 0.885 | 0.857 | 0.850 | 0.832 | 0.895 |
| Feb. | 0.872 | 0.815 | 0.876 | 0.678 | 0.890 | 0.964 | 0.913 | 0.914 | 0.911 | 0.926 |
| Mar. | 0.955 | 0.880 | 0.939 | 0.834 | 0.955 | 1.017 | 0.970 | 1.078 | 0.991 | 0.964 |
| Apr. | 1.039 | 0.982 | 0.998 | 0.962 | 1.023 | 1.030 | 1.017 | 1.100 | 1.005 | 1.011 |
| May. | 1.128 | 1.094 | 1.036 | 1.106 | 1.045 | 1.034 | 1.043 | 1.048 | 0.998 | 1.044 |
| Jun. | 1.142 | 1.190 | 1.112 | 1.174 | 1.109 | 1.060 | 1.104 | 1.088 | 1.028 | 1.069 |
| Jul. | 1.038 | 1.186 | 1.077 | 1.160 | 1.087 | 0.981 | 1.030 | 0.994 | 1.009 | 0.991 |
| Aug. | 1.066 | 1.196 | 1.087 | 1.210 | 1.095 | 1.037 | 1.063 | 1.030 | 1.092 | 1.101 |
| Sep. | 1.069 | 1.099 | 1.085 | 1.234 | 1.042 | 1.032 | 1.058 | 1.023 | 1.061 | 1.071 |
| Oct. | 1.125 | 1.062 | 1.085 | 1.219 | 1.058 | 1.066 | 1.095 | 1.059 | 1.099 | 1.125 |
| Nov. | 0.985 | 0.911 | 0.979 | 1.008 | 0.958 | 0.995 | 0.976 | 0.941 | 1.014 | 0.968 |
| Dec. | 0.810 | 0.823 | 0.890 | 0.773 | 0.910 | 0.899 | 0.874 | 0.875 | 0.960 | 0.835 |

### Table B-7. Monthly Adjustment, >70 & Urban Cluster

| Month | Class 4 | Class 5 | Class 6 | Class 7 | Class 8 | Class 9 | Class 10 | Class 11 | Class 12 | Class 13 |
|---|---|---|---|---|---|---|---|---|---|---|
| Jan. | 0.840 | 0.805 | 0.860 | 0.560 | 0.850 | 0.885 | 0.855 | 0.860 | 0.840 | 0.760 |
| Feb. | 0.925 | 0.850 | 0.885 | 0.585 | 0.895 | 0.955 | 0.885 | 0.910 | 0.905 | 0.810 |
| Mar. | 1.020 | 0.930 | 0.970 | 0.735 | 0.990 | 1.040 | 0.970 | 1.045 | 1.030 | 0.865 |
| Apr. | 1.010 | 0.995 | 0.995 | 1.050 | 1.000 | 1.025 | 1.015 | 1.055 | 1.000 | 0.980 |
| May. | 1.125 | 1.080 | 1.045 | 1.215 | 0.995 | 1.015 | 1.025 | 1.030 | 0.980 | 1.050 |
| Jun. | 1.095 | 1.145 | 1.075 | 1.235 | 1.075 | 1.060 | 1.095 | 1.060 | 1.025 | 1.155 |
| Jul. | 0.965 | 1.085 | 1.025 | 1.190 | 1.010 | 0.945 | 1.045 | 0.990 | 0.960 | 1.105 |
| Aug. | 1.015 | 1.115 | 1.065 | 1.315 | 1.050 | 1.045 | 1.130 | 1.050 | 1.070 | 1.210 |
| Sep. | 1.060 | 1.060 | 1.065 | 1.210 | 1.005 | 1.025 | 1.070 | 1.030 | 1.020 | 1.135 |
| Oct. | 1.085 | 1.065 | 1.080 | 1.215 | 1.090 | 1.075 | 1.115 | 1.085 | 1.095 | 1.205 |
| Nov. | 1.005 | 0.965 | 1.020 | 1.020 | 1.040 | 1.025 | 0.960 | 0.995 | 1.080 | 0.980 |
| Dec. | 0.855 | 0.905 | 0.915 | 0.670 | 1.000 | 0.905 | 0.835 | 0.890 | 0.995 | 0.745 |

### Table B-8. Monthly Adjustment, Non-freeway Statewide Average

| Month | Class 4 | Class 5 | Class 6 | Class 7 | Class 8 | Class 9 | Class 10 | Class 11 | Class 12 | Class 13 |
|---|---|---|---|---|---|---|---|---|---|---|
| Jan. | 0.878 | 0.827 | 0.836 | 0.703 | 0.776 | 0.891 | 0.778 | 0.839 | 0.865 | 0.837 |
| Feb. | 0.978 | 0.865 | 0.842 | 0.706 | 0.829 | 0.959 | 0.831 | 0.914 | 0.913 | 0.874 |
| Mar. | 0.986 | 0.857 | 0.825 | 0.735 | 0.855 | 0.991 | 0.882 | 0.939 | 0.845 | 0.873 |
| Apr. | 0.982 | 0.878 | 0.895 | 0.814 | 0.915 | 0.996 | 0.902 | 0.974 | 0.947 | 0.920 |
| May. | 1.129 | 1.054 | 1.047 | 1.067 | 1.052 | 1.024 | 1.021 | 1.150 | 1.026 | 1.039 |
| Jun. | 0.989 | 1.117 | 1.119 | 1.220 | 1.185 | 1.055 | 1.156 | 1.300 | 1.021 | 1.090 |
| Jul. | 0.904 | 1.194 | 1.106 | 1.247 | 1.216 | 1.014 | 1.070 | 1.043 | 0.997 | 1.062 |
| Aug. | 0.955 | 1.230 | 1.183 | 1.304 | 1.301 | 1.087 | 1.194 | 1.041 | 1.027 | 1.181 |
| Sep. | 1.156 | 1.167 | 1.185 | 1.331 | 1.152 | 1.050 | 1.176 | 0.965 | 0.994 | 1.083 |
| Oct. | 1.182 | 1.069 | 1.151 | 1.223 | 1.036 | 1.073 | 1.202 | 0.973 | 1.133 | 1.214 |
| Nov. | 1.022 | 0.904 | 0.950 | 0.938 | 0.878 | 0.969 | 0.958 | 0.928 | 1.064 | 1.009 |
| Dec. | 0.839 | 0.837 | 0.861 | 0.711 | 0.805 | 0.891 | 0.831 | 0.934 | 1.167 | 0.820 |

### Table B-9. Monthly Adjustment, Freeway Statewide Average

| Month | Class 4 | Class 5 | Class 6 | Class 7 | Class 8 | Class 9 | Class 10 | Class 11 | Class 12 | Class 13 |
|---|---|---|---|---|---|---|---|---|---|---|
| Jan. | 0.804 | 0.776 | 0.828 | 0.643 | 0.816 | 0.889 | 0.819 | 0.864 | 0.836 | 0.796 |
| Feb. | 0.889 | 0.813 | 0.849 | 0.674 | 0.866 | 0.954 | 0.858 | 0.923 | 0.884 | 0.820 |
| Mar. | 0.948 | 0.867 | 0.897 | 0.813 | 0.937 | 1.019 | 0.917 | 1.038 | 0.978 | 0.859 |
| Apr. | 1.010 | 0.939 | 0.974 | 0.968 | 0.996 | 1.032 | 0.980 | 1.052 | 1.016 | 0.963 |
| May. | 1.139 | 1.053 | 1.038 | 1.115 | 1.036 | 1.024 | 1.050 | 1.040 | 0.987 | 1.069 |
| Jun. | 1.148 | 1.167 | 1.122 | 1.223 | 1.122 | 1.060 | 1.120 | 1.106 | 1.030 | 1.142 |
| Jul. | 0.991 | 1.203 | 1.081 | 1.163 | 1.110 | 0.985 | 1.075 | 1.021 | 0.999 | 1.074 |
| Aug. | 1.086 | 1.227 | 1.116 | 1.199 | 1.140 | 1.046 | 1.122 | 1.047 | 1.066 | 1.162 |
| Sep. | 1.105 | 1.131 | 1.099 | 1.201 | 1.079 | 1.033 | 1.091 | 1.018 | 1.071 | 1.130 |
| Oct. | 1.115 | 1.075 | 1.113 | 1.223 | 1.058 | 1.061 | 1.141 | 1.062 | 1.066 | 1.204 |
| Nov. | 0.966 | 0.914 | 0.994 | 1.027 | 0.945 | 0.993 | 0.982 | 0.954 | 1.017 | 0.984 |
| Dec. | 0.800 | 0.837 | 0.889 | 0.751 | 0.895 | 0.905 | 0.845 | 0.873 | 1.050 | 0.795 |

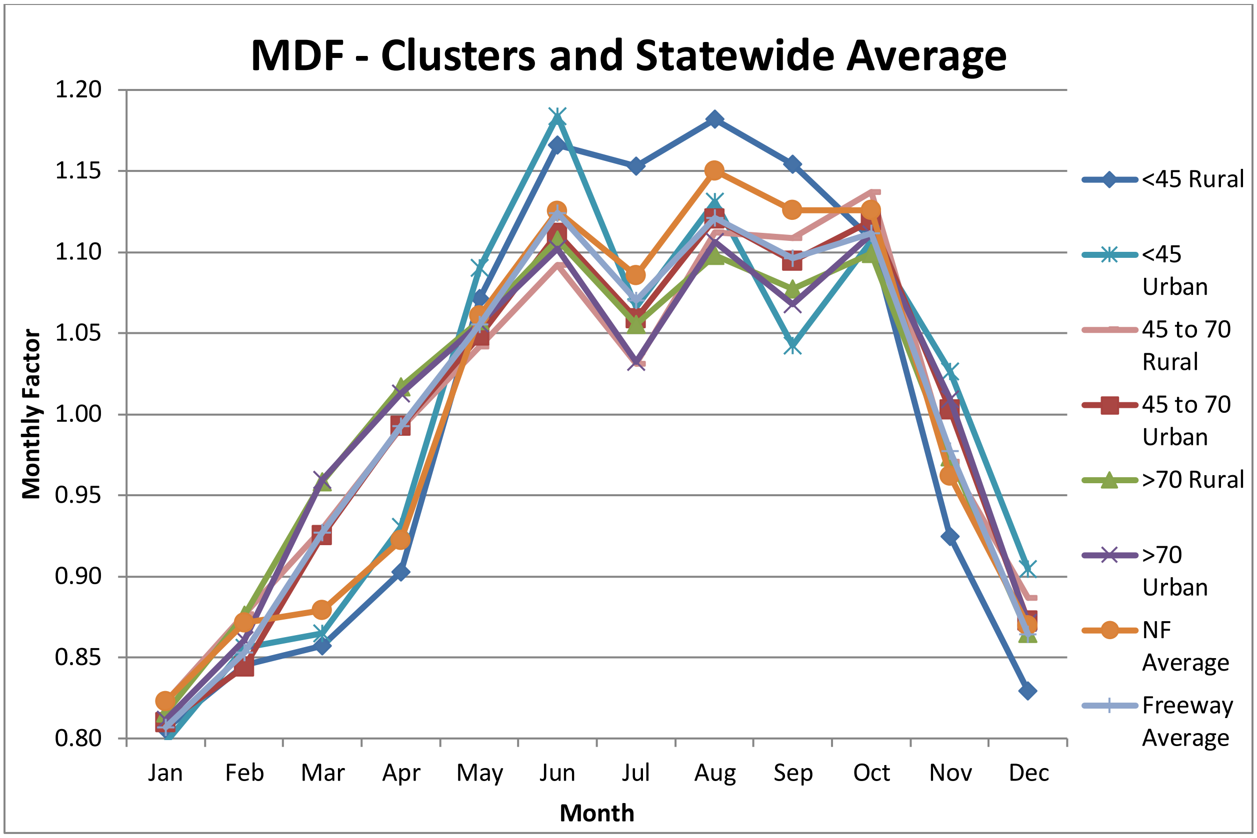



**Figure B-2. Graphical Representation of Monthly Distribution**

### APPENDIX B.3 – Axles Per Truck

**Table B-10. Axles Per Truck, Statewide Average**

| Class | Single | Tandem | Tridem | Quad |
|---|---|---|---|---|
| 4 | 1.60 | 0.40 | 0.00 | 0.00 |
| 5 | 2.00 | 0.00 | 0.00 | 0.00 |
| 6 | 1.00 | 1.00 | 0.00 | 0.00 |
| 7 | 1.08 | 0.06 | 0.51 | 0.43 |
| 8 | 2.16 | 0.84 | 0.00 | 0.00 |
| 9 | 1.21 | 1.89 | 0.00 | 0.00 |
| 10 | 1.00 | 1.00 | 0.40 | 0.60 |
| 11 | 5.00 | 0.00 | 0.00 | 0.00 |
| 12 | 4.00 | 1.00 | 0.00 | 0.00 |
| 13 | 2.40 | 1.56 | 0.51 | 0.27 |

## APPENDIX B.4 – Hourly Adjustment

**Table B-11. Hourly Adjustment, Clusters and Statewide Average**

| Hour | <45 Rural | <45 Urban | 45to70 Rural | 45to70 Urban | >70 Rural | >70 Urban | NF Average | Freeway Average |
|---|---|---|---|---|---|---|---|---|
| 12:00 AM | 0.93 | 0.93 | 1.59 | 1.71 | 2.25 | 2.45 | 1.06 | 1.78 |
| 1:00 AM | 0.86 | 0.85 | 1.44 | 1.53 | 1.99 | 2.05 | 0.99 | 1.58 |
| 2:00 AM | 0.94 | 1.08 | 1.46 | 1.57 | 1.90 | 2.15 | 1.09 | 1.58 |
| 3:00 AM | 1.28 | 1.53 | 1.81 | 1.81 | 2.06 | 2.15 | 1.46 | 1.83 |
| 4:00 AM | 1.79 | 2.18 | 2.36 | 2.39 | 2.44 | 2.50 | 2.03 | 2.33 |
| 5:00 AM | 2.73 | 3.15 | 3.30 | 3.31 | 3.02 | 2.95 | 2.96 | 3.15 |
| 6:00 AM | 4.28 | 4.88 | 4.44 | 4.54 | 3.76 | 3.75 | 4.52 | 4.22 |
| 7:00 AM | 5.55 | 6.53 | 5.31 | 5.47 | 4.44 | 4.40 | 5.79 | 5.10 |
| 8:00 AM | 6.38 | 7.60 | 6.11 | 6.16 | 5.04 | 4.70 | 6.61 | 5.81 |
| 9:00 AM | 6.85 | 7.88 | 6.78 | 6.51 | 5.49 | 5.15 | 7.15 | 6.25 |
| 10:00 AM | 7.23 | 8.18 | 7.14 | 6.91 | 5.73 | 5.90 | 7.54 | 6.60 |
| 11:00 AM | 7.58 | 7.85 | 7.22 | 6.95 | 5.83 | 5.70 | 7.66 | 6.70 |
| 12:00 PM | 7.50 | 7.38 | 7.01 | 6.64 | 5.83 | 5.75 | 7.44 | 6.54 |
| 1:00 PM | 7.35 | 7.15 | 6.78 | 6.51 | 5.80 | 5.70 | 7.22 | 6.43 |
| 2:00 PM | 7.15 | 6.88 | 6.42 | 6.31 | 5.80 | 5.65 | 6.94 | 6.27 |
| 3:00 PM | 6.71 | 6.15 | 5.84 | 5.80 | 5.70 | 6.05 | 6.42 | 5.88 |
| 4:00 PM | 5.99 | 5.18 | 5.11 | 5.13 | 5.52 | 5.25 | 5.61 | 5.32 |
| 5:00 PM | 4.93 | 3.93 | 4.26 | 4.32 | 5.22 | 5.00 | 4.45 | 4.68 |
| 6:00 PM | 3.89 | 3.18 | 3.62 | 3.82 | 4.82 | 4.70 | 3.52 | 4.14 |
| 7:00 PM | 2.98 | 2.23 | 2.97 | 3.21 | 4.34 | 4.30 | 2.67 | 3.53 |
| 8:00 PM | 2.36 | 1.83 | 2.58 | 2.77 | 3.83 | 3.95 | 2.19 | 3.05 |
| 9:00 PM | 1.95 | 1.40 | 2.39 | 2.45 | 3.44 | 3.65 | 1.88 | 2.71 |
| 10:00 PM | 1.58 | 1.18 | 2.17 | 2.21 | 3.09 | 3.30 | 1.56 | 2.43 |
| 11:00 PM | 1.19 | 0.95 | 1.88 | 1.94 | 2.66 | 2.85 | 1.24 | 2.09 |

**NOTE:** NF is “Non-Freeway”

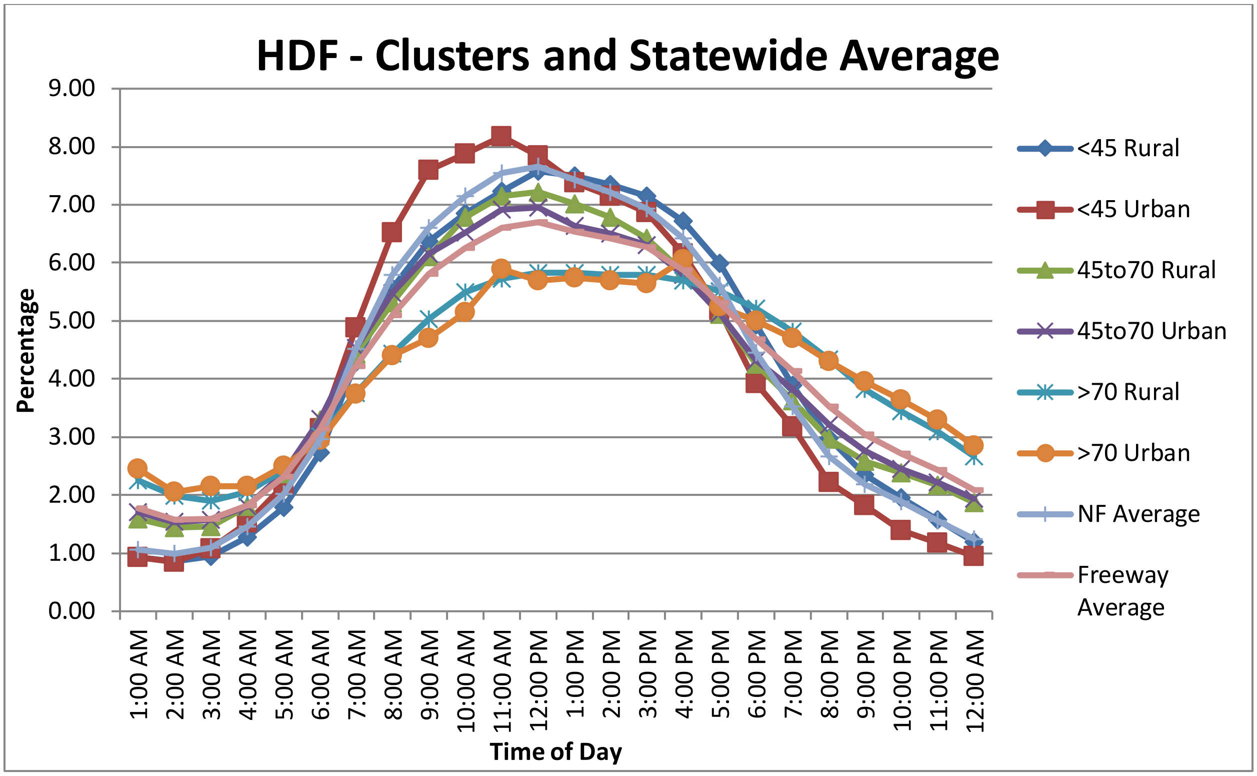



**Figure B-3. Graphical Representation of Hourly Adjustment**

## APPENDIX B.5 – Single Axle Distribution

See the excel file, METrafficData_Dec2019.xlsx and 'Single ALS' tab for single axle distribution of clusters and non-freeway/freeway statewide averages. The following roadway/traffic characteristics per their listed value categories were used to group the WIM sites and establish the clusters:

- Rural/Urban designation (per Adjusted Census Urban Boundary Codes)
  - Urban
  - Rural
- Corridors of Highest Significance (COHS) designation
  - National
  - Regional
  - Statewide

## APPENDIX B.6 – Tandem Axle Distribution

See the excel file, METrafficData_Dec2019.xlsx and 'Tandem ALS' tab for single axle distribution of clusters and non-freeway/freeway statewide averages. The following roadway/traffic characteristics per their listed value categories were used to group the WIM sites and establish the clusters:

- Rural/Urban designation (per Adjusted Census Urban Boundary Codes)
  - Urban
  - Rural

- Number of lanes
    - 2
    - 3
    - 4 or more

**APPENDIX B.7 – Tridem Axle Distribution**

See the excel file, METrafficData_Dec2019.xlsx and 'Tridem ALS' tab for single axle distribution of clusters and non-freeway/freeway statewide averages. The following roadway/traffic characteristics per their listed value categories were used to group the WIM sites and establish the clusters:

- Rural/Urban designation (per Adjusted Census Urban Boundary Codes)
    - Urban
    - Rural
- COHS designation
    - National
    - Regional
    - Statewide

**APPENDIX B.8 – Quad Axle Distribution**

See the excel file, METrafficData_Dec2019.xlsx and 'Quad ALS' tab for single axle distribution of clusters and non-freeway/freeway statewide averages. The following roadway/traffic characteristics per their listed value categories were used to group the WIM sites and establish the clusters:

- Rural/Urban designation (per Adjusted Census Urban Boundary Codes)
    - Urban
    - Rural
- COHS designation
    - National
    - Regional
    - Statewide

## APPENDIX C - Example ME Output Reports

The following appendix sections display ME software PDF Output Reports for an example MDOT project. The outputs for a new jointed plain concrete pavement (JPCP) design are shown in Appendix C.1 and the outputs for a new hot mix asphalt (HMA) pavement design are shown in Appendix C.2. The JPCP report includes 15 pages and the HMA report includes 24 pages. The following is background information for the project designs:

- Location
  - US-31, 8th Avenue to Quincy Rd
  - MDOT Grand Region
- Subgrade
  - Soils indicate USCS type SP-SM
- Climate Station
  - Nearest single weather station = Muskegon
- Traffic Information
  - ESALs = 12,163,800(rigid) / 8,486,370(flexible)
  - CADT = 2932
  - Monthly Adjustment = [CADT 1000 to 3000]/[Urban] Cluster
  - Vehicle Class Distribution = Short-Counts
  - Hourly Adjustment = Short-Counts
  - Tandem Axle Load Distribution = [COHS Statewide]/[Urban] Cluster
  - Tandem Axle Load Distribution = [2 Lanes]/[Urban] Cluster
  - Tridem Axle Load Distribution = [COHS Statewide]/[Urban] Cluster
  - Quad Axle Load Distribution = [COHS Statewide]/[Urban] Cluster
- Initial Design (AASHTO 1993)
  - Jointed Plain Concrete (New)
    - 9.5”, 14’ joint spacing, 1.25” dowel bar diameter
    - 6” OGDC, 10” Sand Subbase
  - HMA Hot Mix Asphalt (New)
    - 1.5” 5E10 PG64-28 (for ME, test results for E*, D(t), & IDT)
    - 3.25” 3E10 PG64-28 (for ME, predicted results for E*, D(t), & IDT)
    - 3.5” 3E10 PG58-22 (for ME, test results for E*, D(t), & IDT)
    - 6” OGDC, 18” Sand Subbase

## APPENDIX C.1 – Jointed Plain Concrete (New) Pavement Design Example ME Output Report

# JN 88876 & 90076 & 90077 - JPCP(1)

File Name: C:\Users\schenkelj\Documents\My ME Design\My ME Design\JN 88876 & 90076 & 90077 - JPCP(1).dgpx

## Design Inputs

Design Life: 20 years
Design Type: JPCP

Existing construction: -
Pavement construction: August, 2016
Traffic opening: September, 2016

Climate Data Sources (Lat/Lon): 43.171, -86.237

### Design Structure

| Layer type | Material Type | Thickness (in) |
|---|---|---|
| PCC | JPCP | 9.5 |
| NonStabilized | OGDC | 6.0 |
| NonStabilized | Sand Subbase | 10.0 |
| Subgrade | Poorly Graded Sand/Silty Sand Subgrade | Semi-infinite |

| Joint Design: | |
|---|---|
| Joint spacing (ft) | 14.0 |
| Dowel diameter (in) | 1.25 |
| Slab width (ft) | 12.0 |

### Traffic

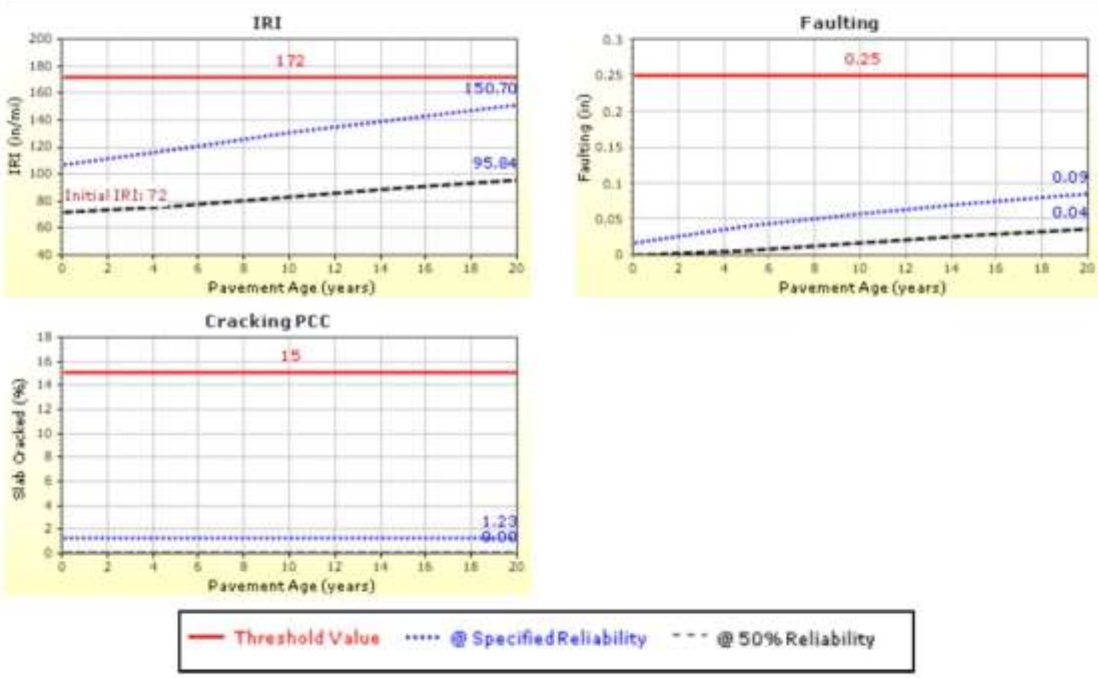
| Age (year) | Heavy Trucks (cumulative) |
|---|---|
| 2016 (initial) | 2,932 |
| 2026 (10 years) | 4,529,990 |
| 2036 (20 years) | 9,435,710 |

## Design Outputs

### Distress Prediction Summary

| Distress Type | Distress @ Specified Reliability | | Reliability (%) | | Criterion Satisfied? |
|---|---|---|---|---|---|
| | Target | Predicted | Target | Achieved | |
| Terminal IRI (in/mile) | 172.00 | 150.70 | 95.00 | 98.88 | Pass |
| Mean joint faulting (in) | 0.25 | 0.09 | 95.00 | 100.00 | Pass |
| JPCP transverse cracking (percent slabs) | 15.00 | 1.23 | 95.00 | 100.00 | Pass |

### Distress Charts

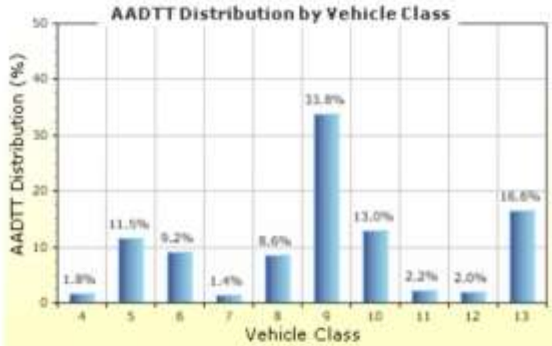



Report generated on: 12/2/2019 5:26 PM | Version: 2.3.0+65 | Created by: J Schenkel on: 6/16/2014 1:41 PM | Approved by: on: 6/16/2014 1:41 PM | Page 1 of 15

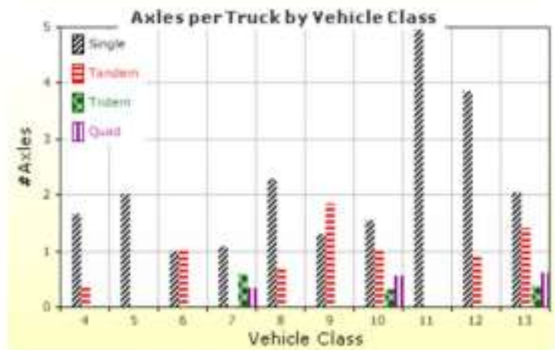
# Traffic Inputs

## Graphical Representation of Traffic Inputs

| | | | |
|---|---|---|---|
| Initial two-way AADTT: | 2,932 | Percent of trucks in design direction (%): | 51.0 |
| Number of lanes in design direction: | 2 | Percent of trucks in design lane (%): | 80.0 |
| | | Operational speed (mph) | 55.0 |






## Tabular Representation of Traffic Inputs

### Volume Monthly Adjustment Factors

Level 3: Default MAF

| Month | Vehicle Class 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|
| January | 0.8 | 0.8 | 0.8 | 0.6 | 0.8 | 0.9 | 0.8 | 0.9 | 0.8 | 0.8 |
| February | 0.9 | 0.8 | 0.9 | 0.6 | 0.9 | 0.9 | 0.8 | 0.9 | 0.9 | 0.8 |
| March | 1.0 | 0.9 | 0.9 | 0.8 | 1.0 | 1.0 | 0.9 | 1.0 | 1.0 | 0.8 |
| April | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 |
| May | 1.1 | 1.0 | 1.0 | 1.2 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.1 |
| June | 1.1 | 1.1 | 1.1 | 1.2 | 1.1 | 1.0 | 1.1 | 1.1 | 1.0 | 1.1 |
| July | 1.0 | 1.1 | 1.1 | 1.2 | 1.1 | 1.0 | 1.1 | 1.0 | 1.0 | 1.1 |
| August | 1.0 | 1.2 | 1.1 | 1.2 | 1.1 | 1.0 | 1.1 | 1.0 | 1.0 | 1.2 |
| September | 1.1 | 1.1 | 1.1 | 1.2 | 1.0 | 1.1 | 1.1 | 1.0 | 1.0 | 1.2 |
| October | 1.1 | 1.1 | 1.1 | 1.2 | 1.1 | 1.1 | 1.2 | 1.1 | 1.1 | 1.3 |
| November | 1.0 | 0.9 | 1.0 | 1.0 | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| December | 0.8 | 0.9 | 0.9 | 0.7 | 0.9 | 0.9 | 0.9 | 0.9 | 1.0 | 0.8 |

### Distributions by Vehicle Class

| Vehicle Class | AADTT Distribution (%) (Level 3) | Growth Factor Rate (%) | Growth Factor Function |
|---|---|---|---|
| Class 4 | 1.78% | 0.8% | Compound |
| Class 5 | 11.5% | 0.8% | Compound |
| Class 6 | 9.17% | 0.8% | Compound |
| Class 7 | 1.4% | 0.8% | Compound |
| Class 8 | 8.62% | 0.8% | Compound |
| Class 9 | 33.77% | 0.8% | Compound |
| Class 10 | 12.96% | 0.8% | Compound |
| Class 11 | 2.21% | 0.8% | Compound |
| Class 12 | 1.97% | 0.8% | Compound |
| Class 13 | 16.62% | 0.8% | Compound |

### Truck Distribution by Hour

| Hour | Distribution (%) | Hour | Distribution (%) |
|---|---|---|---|
| 12 AM | 1% | 12 PM | 7.69% |
| 1 AM | 1% | 1 PM | 6.95% |
| 2 AM | 1.04% | 2 PM | 7.02% |
| 3 AM | 1.11% | 3 PM | 7.5% |
| 4 AM | 1.41% | 4 PM | 5.76% |
| 5 AM | 2.3% | 5 PM | 5.16% |
| 6 AM | 4.38% | 6 PM | 2.64% |
| 7 AM | 7.17% | 7 PM | 1.78% |
| 8 AM | 7.8% | 8 PM | 1.78% |
| 9 AM | 7.54% | 9 PM | 1.37% |
| 10 AM | 7.99% | 10 PM | 1.23% |
| 11 AM | 7.43% | 11 PM | 0.95% |
| | | Total | 100% |

### Axle Configuration

| Traffic Wander | |
|---|---|
| Mean wheel location (in) | 18.0 |
| Traffic wander standard deviation (in) | 10.0 |
| Design lane width (ft) | 12.0 |

| Axle Configuration | |
|---|---|
| Average axle width (ft) | 8.5 |
| Dual tire spacing (in) | 12.0 |
| Tire pressure (psi) | 120.0 |

| Average Axle Spacing | |
|---|---|
| Tandem axle spacing (in) | 51.6 |
| Tridem axle spacing (in) | 49.2 |
| Quad axle spacing (in) | 49.2 |

| Wheelbase: Value Type / Axle Type | Short | Medium | Long |
|---|---|---|---|
| Average spacing of axles (ft) | 12.0 | 15.0 | 18.0 |
| Percent of Trucks (%) | 17.0 | 22.0 | 61.0 |

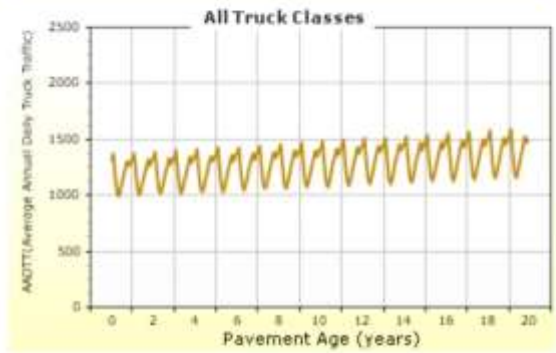
### Number of Axles per Truck

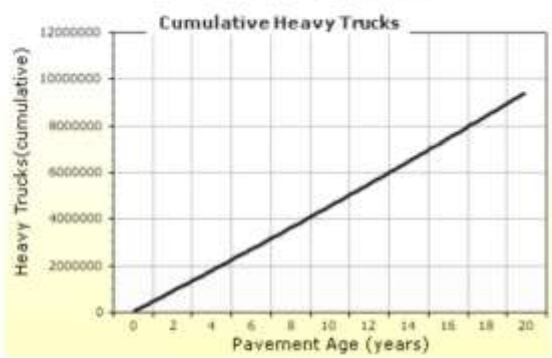
| Vehicle Class | Single Axle | Tandem Axle | Tridem Axle | Quad Axle |
|---|---|---|---|---|
| Class 4 | 1.65 | 0.36 | 0 | 0 |
| Class 5 | 2 | 0.05 | 0 | 0 |
| Class 6 | 1 | 1 | 0 | 0 |
| Class 7 | 1.06 | 0.06 | 0.59 | 0.35 |
| Class 8 | 2.28 | 0.74 | 0 | 0 |
| Class 9 | 1.29 | 1.85 | 0 | 0 |
| Class 10 | 1.54 | 1 | 0.31 | 0.56 |
| Class 11 | 4.99 | 0 | 0 | 0 |
| Class 12 | 3.85 | 0.96 | 0 | 0 |
| Class 13 | 2.03 | 1.4 | 0.36 | 0.61 |

## AADTT (Average Annual Daily Truck Traffic) Growth

*** Traffic cap is not enforced**



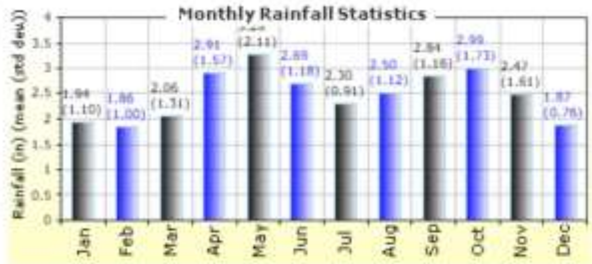



# Climate Inputs

## Climate Data Sources:

| Climate Station Cities: | Location (lat lon elevation(ft)) |
|---|---|
| MUSKEGON, MI | 43.17100 -86.23700 626 |

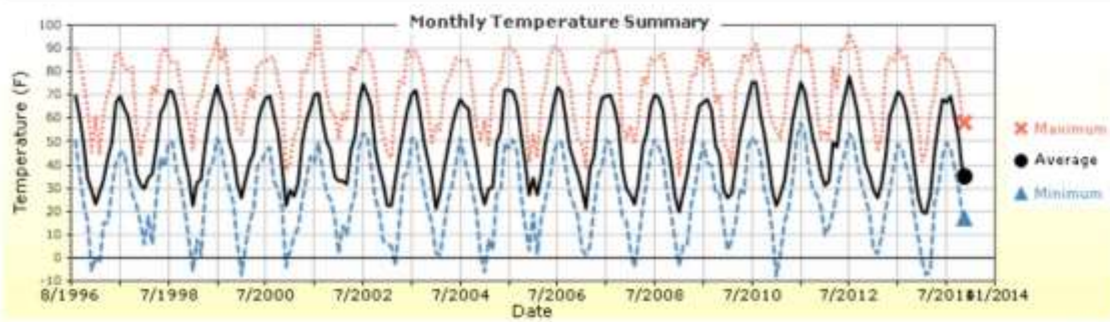


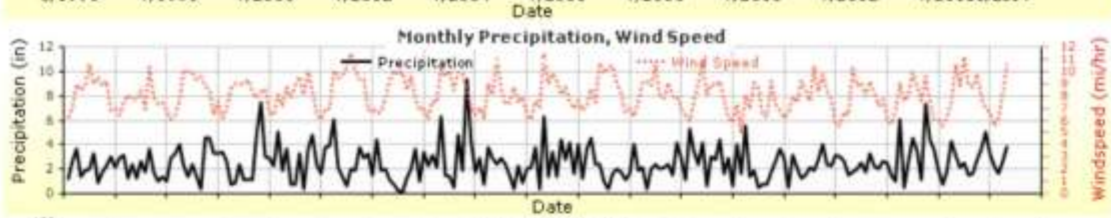

## Annual Statistics:

| | |
|---|---|
| Mean annual air temperature (ºF) | 49.23 |
| Mean annual precipitation (in) | 29.73 |
| Freezing index (ºF - days) | 606.21 |
| Average annual number of freeze/thaw cycles: | 57.77 |

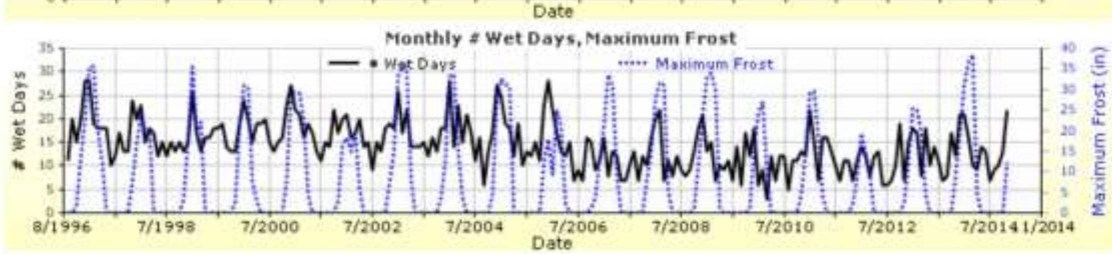
Water table depth (ft) 5.00

## Monthly Climate Summary:



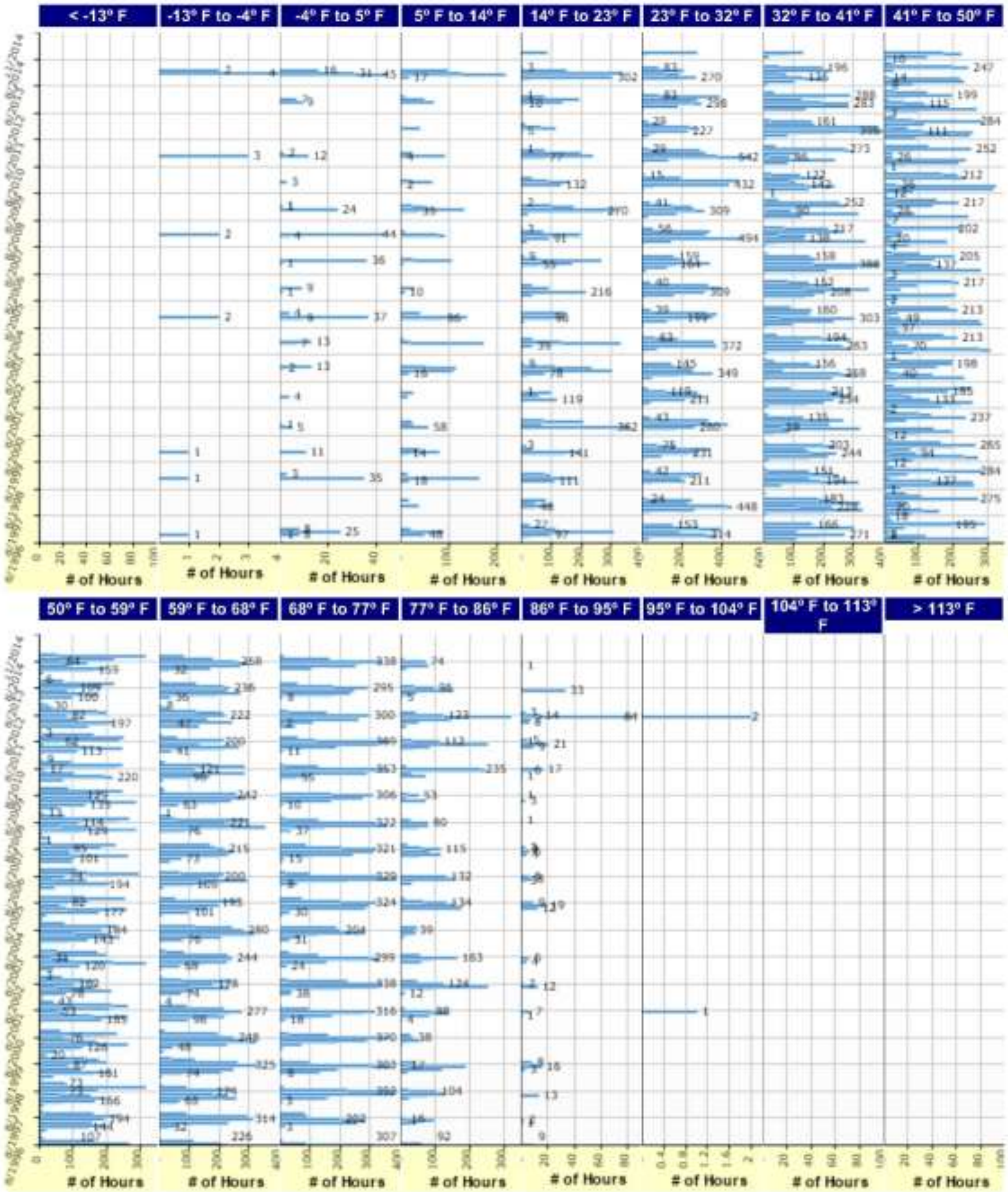




# JN 88876 & 90076 & 90077 - JPCP(1)

File Name: C:\Users\schenkelj\Documents\My ME Design\My ME Design\JN 88876 & 90076 & 90077 - JPCP(1).dgpx

## Hourly Air Temperature Distribution by Month:




Report generated on: 12/2/2019 5:26 PM | Version: 2.3.0+65 | Created by: J Schenkel on: 6/16/2014 1:41 PM | Approved by: on: 6/16/2014 1:41 PM | Page 6 of 15

## Design Properties

### JPCP Design Properties

| Structure - ICM Properties | |
|---|---|
| PCC surface shortwave absorptivity | 0.85 |

| PCC joint spacing (ft) | |
|---|---|
| Is joint spacing random ? | False |
| Joint spacing (ft) | 14.00 |

| Doweled Joints | |
|---|---|
| Is joint doweled ? | True |
| Dowel diameter (in) | 1.25 |
| Dowel spacing (in) | 12.00 |

| Widened Slab | |
|---|---|
| Is slab widened ? | False |
| Slab width (ft) | 12.00 |

| | |
|---|---|
| **Sealant type** | Other(Including No Sealant... Liquid... Silicone) |

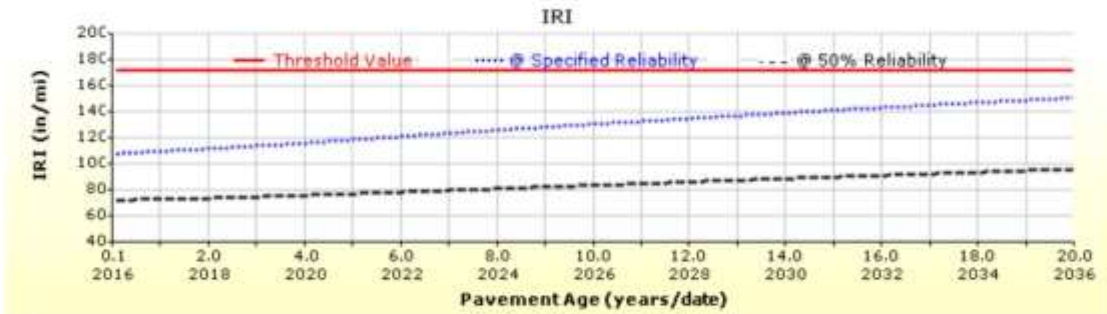
| Tied Shoulders | |
|---|---|
| Tied shoulders | True |
| Load transfer efficiency (%) | 50.00 |

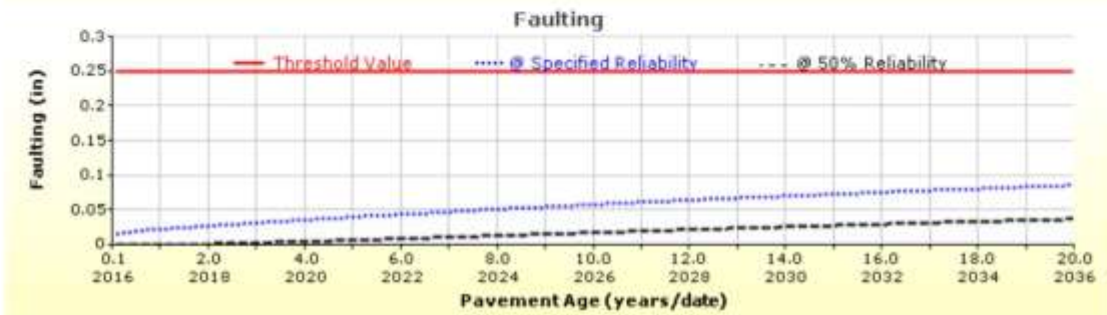
| PCC-Base Contact Friction | |
|---|---|
| PCC-Base full friction contact | True |
| Months until friction loss | 60.00 |

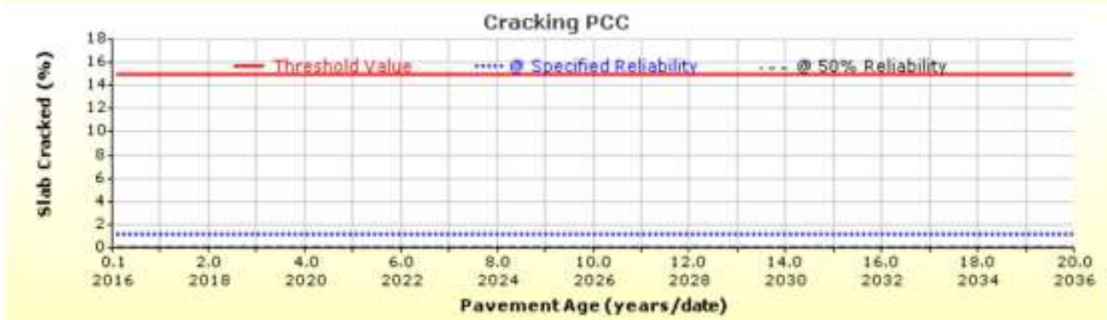
| | |
|---|---|
| **Erodibility index** | 4 |

| | |
|---|---|
| **Permanent curl/warp effective temperature difference (°F)** | -10.00 |

## Analysis Output Charts



# JN 88876 & 90076 & 90077 - JPCP(1)

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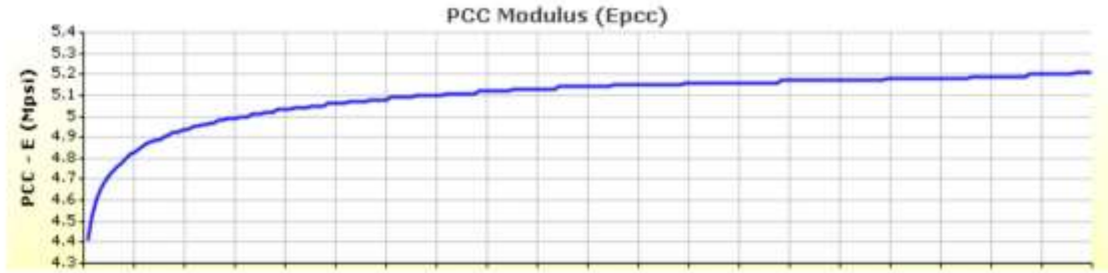
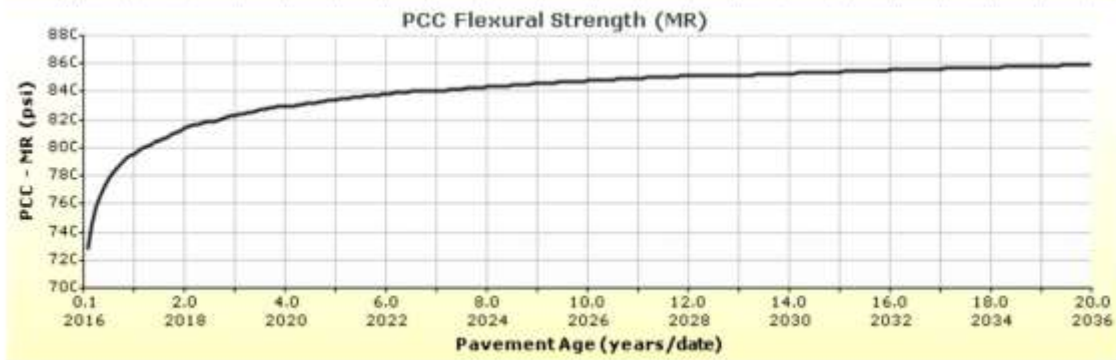
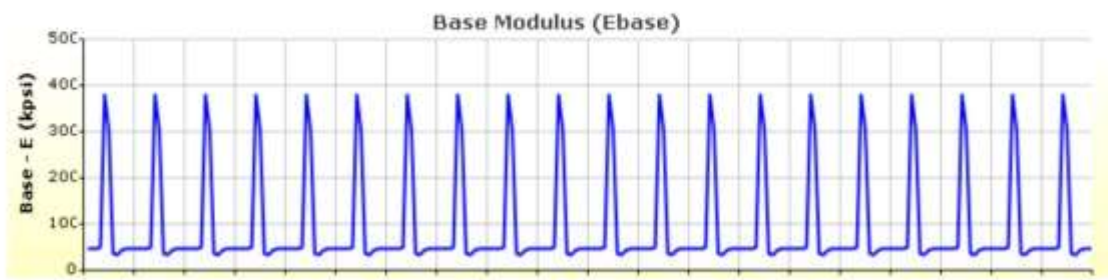
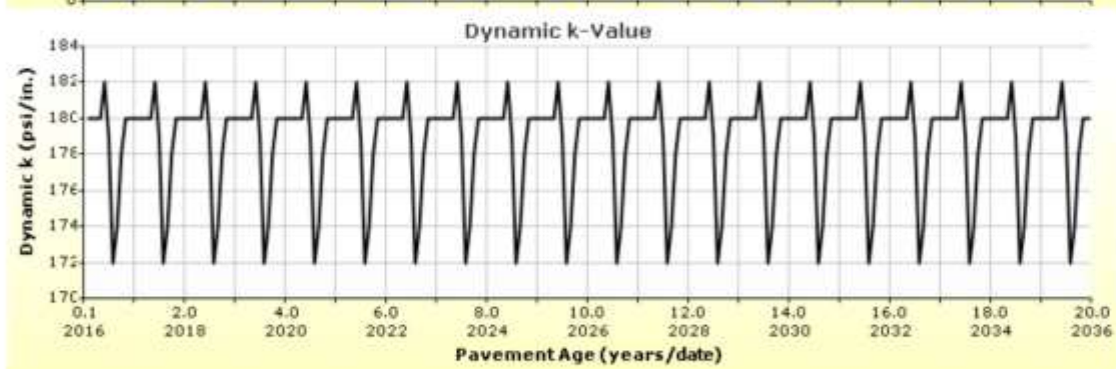
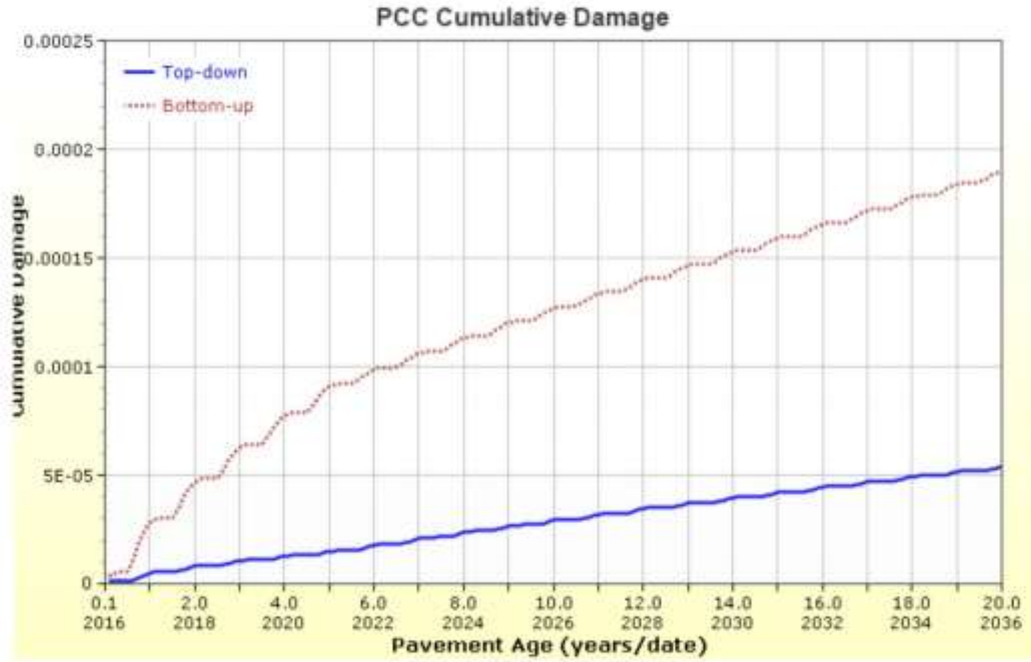
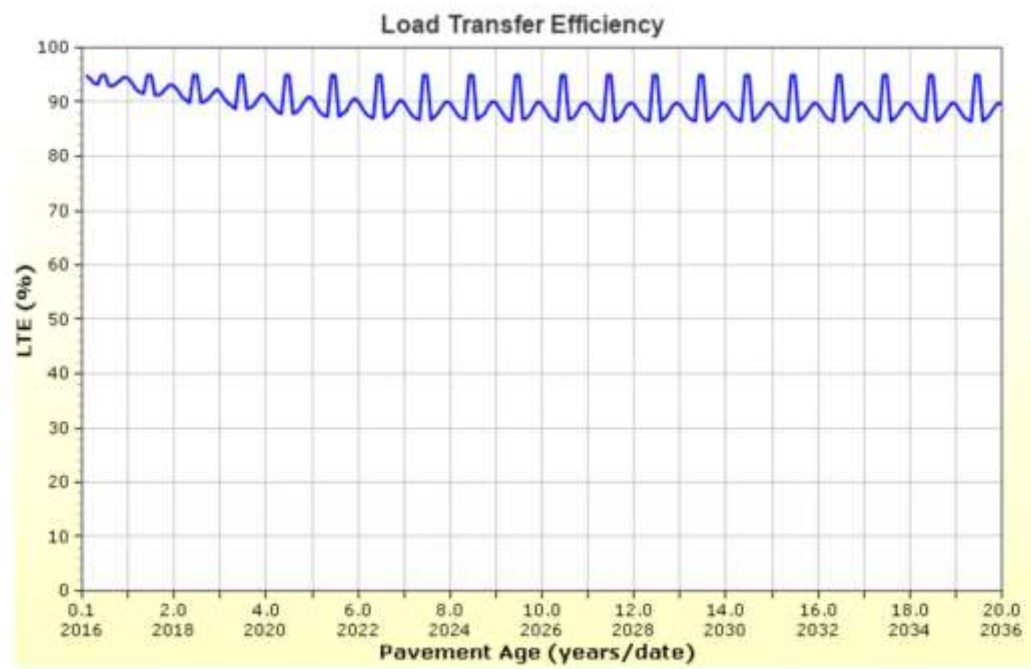



PCC Cumulative Damage
Top-down
Bottom-up
Cumulative Damage
0.00025
0.0002
0.00015
0.0001
5E-05
0
0.1 2016
2.0 2018
4.0 2020
6.0 2022
8.0 2024
10.0 2026
12.0 2028
14.0 2030
16.0 2032
18.0 2034
20.0 2036
Pavement Age (years/date)


Load Transfer Efficiency
LTE (%)
100
90
80
70
60
50
40
30
20
10
0
0.1 2016
2.0 2018
4.0 2020
6.0 2022
8.0 2024
10.0 2026
12.0 2028
14.0 2030
16.0 2032
18.0 2034
20.0 2036
Pavement Age (years/date)

# JN 88876 & 90076 & 90077 - JPCP(1)

File Name: C:\Users\schenkelj\Documents\My ME Design\My ME Design\JN 88876 & 90076 & 90077 - JPCP(1).dgpx

## Layer Information

### Layer 1 PCC : JPCP

| PCC | |
|---|---|
| Thickness (in) | 9.5 |
| Unit weight (pcf) | 145.0 |
| Poisson's ratio | 0.2 |

| Thermal | |
|---|---|
| PCC coefficient of thermal expansion (in/in/°F x 10^-6) | 4.5 |
| PCC thermal conductivity (BTU/hr-ft-°F) | 1.25 |
| PCC heat capacity (BTU/lb-°F) | 0.28 |

| Mix | | |
|---|---|---|
| Cement type | | Type I (1) |
| Cementitious material content (lb/yd^3) | | 500 |
| Water to cement ratio | | 0.42 |
| Aggregate type | | Limestone (1) |
| PCC zero-stress temperature (°F) | Calculated Internally? | True |
| | User Value | - |
| | Calculated Value | 96.8 |
| Ultimate shrinkage (microstrain) | Calculated Internally? | True |
| | User Value | - |
| | Calculated Value | 530.8 |
| Reversible shrinkage (%) | | 50 |
| Time to develop 50% of ultimate shrinkage (days) | | 35 |
| Curing method | | Curing Compound |

#### PCC strength and modulus (Input Level: 3)

| | |
|---|---|
| **28-Day PCC compressive strength (psi)** | 5600.0 |
| **28-Day PCC elastic modulus (psi)** | - |

#### Identifiers

| Field | Value |
|---|---|
| Display name/identifier | JPCP |
| Description of object | |
| Author | |
| Date Created | 7/19/2012 8:17:48AM |
| Approver | |
| Date approved | 7/19/2012 8:17:48AM |
| State | |
| District | |
| County | |
| Highway | |
| Direction of Travel | |
| From station (miles) | |
| To station (miles) | |
| Province | |
| User defined field 1 | |
| User defined field 2 | |
| User defined field 3 | |
| Revision Number | 0 |

## Layer 2 Non-stabilized Base : OGDC

| Unbound | |
|---|---|
| Layer thickness (in) | 6.0 |
| Poisson's ratio | 0.35 |
| Coefficient of lateral earth pressure (k0) | 0.5 |

### Modulus (Input Level: 2)

| | |
|---|---|
| **Analysis Type:** | Modify input values by temperature/moisture |
| **Method:** | Resilient Modulus (psi) |

| Resilient Modulus (psi) |
|---|
| 33000.0 |

| | |
|---|---|
| **Use Correction factor for NDT modulus?** | - |
| **NDT Correction Factor:** | - |

### Identifiers

| Field | Value |
|---|---|
| Display name/identifier | OGDC |
| Description of object | |
| Author | |
| Date Created | 1/1/0001 12:00:00AM |
| Approver | |
| Date approved | 1/1/0001 12:00:00AM |
| State | |
| District | |
| County | |
| Highway | |
| Direction of Travel | |
| From station (miles) | |
| To station (miles) | |
| Province | |
| User defined field 1 | |
| User defined field 2 | |
| User defined field 3 | |
| Revision Number | 0 |

### Sieve

| | |
|---|---|
| **Liquid Limit** | 0.0 |
| **Plasticity Index** | 0.0 |
| **Is layer compacted?** | True |

| | Is User Defined? | Value |
|---|---|---|
| Maximum dry unit weight (pcf) | False | 127 |
| Saturated hydraulic conductivity (ft/hr) | False | 4.322e-01 |
| Specific gravity of solids | False | 2.7 |
| Water Content (%) | False | 6.5 |

| User-defined Soil Water Characteristic Curve (SWCC) | |
|---|---|
| **Is User Defined?** | False |
| **af** | 9.6111 |
| **bf** | 2.9560 |
| **cf** | 0.8456 |
| **hr** | 100.0000 |

| Sieve Size | % Passing |
|---|---|
| 0.001mm | |
| 0.002mm | |
| 0.020mm | |
| #200 | 4.2 |
| #100 | |
| #80 | |
| #60 | |
| #50 | |
| #40 | |
| #30 | 13.7 |
| #20 | |
| #16 | |
| #10 | |
| #8 | 23.6 |
| #4 | |
| 3/8-in. | |
| 1/2-in. | 58.8 |
| 3/4-in. | |
| 1-in. | 93.5 |
| 1 1/2-in. | 100.0 |
| 2-in. | |
| 2 1/2-in. | |
| 3-in. | |
| 3 1/2-in. | |

## Layer 3 Non-stabilized Base : Sand Subbase

| Unbound | |
|---|---|
| Layer thickness (in) | 10.0 |
| Poisson's ratio | 0.35 |
| Coefficient of lateral earth pressure (k0) | 0.5 |

### Modulus (Input Level: 3)

| | |
|---|---|
| **Analysis Type:** | Modify input values by temperature/moisture |
| **Method:** | Resilient Modulus (psi) |

| Resilient Modulus (psi) |
|---|
| 20000.0 |

| | |
|---|---|
| **Use Correction factor for NDT modulus?** | - |
| **NDT Correction Factor:** | - |

### Identifiers

| Field | Value |
|---|---|
| Display name/identifier | Sand Subbase |
| Description of object | |
| Author | |
| Date Created | 1/1/0001 12:00:00AM |
| Approver | |
| Date approved | 1/1/0001 12:00:00AM |
| State | |
| District | |
| County | |
| Highway | |
| Direction of Travel | |
| From station (miles) | |
| To station (miles) | |
| Province | |
| User defined field 1 | |
| User defined field 2 | |
| User defined field 3 | |
| Revision Number | 0 |

### Sieve

| | |
|---|---|
| **Liquid Limit** | 0.0 |
| **Plasticity Index** | 0.0 |
| **Is layer compacted?** | True |

| | Is User Defined? | Value |
|---|---|---|
| Maximum dry unit weight (pcf) | False | 124.6 |
| Saturated hydraulic conductivity (ft/hr) | False | 9.427e-03 |
| Specific gravity of solids | False | 2.7 |
| Water Content (%) | False | 9.5 |

| User-defined Soil Water Characteristic Curve (SWCC) | |
|---|---|
| **Is User Defined?** | False |
| **af** | 5.4729 |
| **bf** | 1.9212 |
| **cf** | 0.8511 |
| **hr** | 100.0000 |

| Sieve Size | % Passing |
|---|---|
| 0.001mm | |
| 0.002mm | |
| 0.020mm | |
| #200 | 4.6 |
| #100 | 15.6 |
| #80 | |
| #60 | |
| #50 | |
| #40 | |
| #30 | |
| #20 | |
| #16 | |
| #10 | |
| #8 | |
| #4 | |
| 3/8-in. | |
| 1/2-in. | |
| 3/4-in. | |
| 1-in. | 99.8 |
| 1 1/2-in. | |
| 2-in. | |
| 2 1/2-in. | |
| 3-in. | |
| 3 1/2-in. | |

## Layer 4 Subgrade : Poorly Graded Sand/Silty Sand Subgrade

| Unbound | |
|---|---|
| Layer thickness (in) | Semi-infinite |
| Poisson's ratio | 0.35 |
| Coefficient of lateral earth pressure (k0) | 0.5 |

### Modulus (Input Level: 3)

| | |
|---|---|
| **Analysis Type:** | Annual representative values |
| **Method:** | Resilient Modulus (psi) |

| Resilient Modulus (psi) |
|---|
| 7000.0 |

| | |
|---|---|
| **Use Correction factor for NDT modulus?** | - |
| **NDT Correction Factor:** | - |

### Identifiers

| Field | Value |
|---|---|
| Display name/identifier | Poorly Graded Sand/Silty Sand |
| Description of object | |
| Author | |
| Date Created | 6/20/2014 12:00:00AM |
| Approver | |
| Date approved | 1/1/0001 12:00:00AM |
| State | |
| District | |
| County | |
| Highway | |
| Direction of Travel | |
| From station (miles) | |
| To station (miles) | |
| Province | |
| User defined field 1 | |
| User defined field 2 | |
| User defined field 3 | |
| Revision Number | 0 |

### Sieve

| | |
|---|---|
| **Liquid Limit** | 15.5 |
| **Plasticity Index** | 5.0 |
| **Is layer compacted?** | True |

| | Is User Defined? | Value |
|---|---|---|
| Maximum dry unit weight (pcf) | True | 113.8 |
| Saturated hydraulic conductivity (ft/hr) | False | 1.938e-03 |
| Specific gravity of solids | False | 2.7 |
| Water Content (%) | False | 8.7 |

| User-defined Soil Water Characteristic Curve (SWCC) | |
|---|---|
| **Is User Defined?** | False |
| **af** | 4.0786 |
| **bf** | 2.2975 |
| **cf** | 0.9252 |
| **hr** | 166.1000 |

| Sieve Size | % Passing |
|---|---|
| 0.001mm | |
| 0.002mm | |
| 0.020mm | |
| #200 | 6.6 |
| #100 | 17.5 |
| #80 | |
| #60 | |
| #50 | |
| #40 | 66.1 |
| #30 | |
| #20 | 79.4 |
| #16 | |
| #10 | 87.2 |
| #8 | |
| #4 | 92.5 |
| 3/8-in. | 96.3 |
| 1/2-in. | |
| 3/4-in. | |
| 1-in. | |
| 1 1/2-in. | |
| 2-in. | |
| 2 1/2-in. | |
| 3-in. | |
| 3 1/2-in. | |

## Calibration Coefficients

**PCC Faulting**

$$C_{12} = C_1 + (C_2 * FR^{0.25})$$
$$C_{34} = C_3 + (C_4 * FR^{0.25})$$
$$FaultMax_0 = C_{12} * \delta_{curling} * \left[\log(1 + C_5 * 5.0^{EROD}) * \log\left(P_{200} * \frac{WetDays}{p_s}\right)\right]^{C_6}$$
$$FaultMax_i = FaultMax_0 + C_7 * \sum_{j=1}^{m} DE_j * \log(1 + C_5 * 5.0^{EROD})^{C_6}$$
$$\Delta Fault_i = C_{34} * (FaultMax_{i-1} - Fault_{i-1})^2 * DE_i$$
$$C_8 = DowelDeterioration$$

| | | | |
|---|---|---|---|
| C1: 0.595 | C2: 1.636 | C3: 0.00217 | C4: 0.00444 |
| C5: 250 | C6: 0.47 | C7: 7.3 | C8: 400 |

**PCC Reliability Faulting Standard Deviation**

0.07162 * Pow(FAULT,0.368) + 0.00806

**IRI-jpcp**

| | | |
|---|---|---|
| C1 - Cracking | C1: 0.8203 | C2: 0.4417 |
| C2 - Spalling | C3: 1.4929 | C4: 25.24 |
| C3 - Faulting | **Reliability Standard Deviation** | |
| C4 - Site Factor | 5.4 | |

**PCC Cracking**

$$\log(N) = C1 \cdot \left(\frac{MR}{\sigma}\right)^{C2}$$

$$CRK = \frac{100}{1 + C4\,FD^{C5}}$$

| Fatigue Coefficients | | Cracking Coefficients | |
|---|---|---|---|
| C1: 2 | C2: 1.22 | C4: 0.52 | C5: -2.17 |

**PCC Reliability Cracking Standard Deviation**

3.5522 * Pow(CRACK,0.3415) + 0.75

## APPENDIX C.2 – Hot Mix Asphalt (New) Pavement Design Example ME Output Report

# JN 88876 & 90076 & 90077 - HMA(1)

File Name: C:\Users\schenkelj\Documents\My ME Design\My ME Design\JN 88876 & 90076 & 90077 - HMA(1).dgpx

## Design Inputs

| | | | | | |
|---|---|---|---|---|---|
| Design Life: | 20 years | Base construction: | July, 2016 | Climate Data Sources (Lat/Lon) | 43.171, -86.237 |
| Design Type: | FLEXIBLE | Pavement construction: | August, 2016 | | |
| | | Traffic opening: | September, 2016 | | |

### Design Structure

| Layer type | Material Type | Thickness (in) |
|---|---|---|
| Flexible | 5E10_TopCourse | 1.5 |
| Flexible | 3E10 Leveling Course | 3.3 |
| Flexible | 3E10_BaseCourse | 3.5 |
| NonStabilized | OGDC | 6.0 |
| NonStabilized | Sand Subbase | 18.0 |
| Subgrade | Poorly Graded Sand/Silty Sand Subgrade | Semi-infinite |

| Volumetric at Construction: | |
|---|---|
| Effective binder content (%) | 12.1 |
| Air voids (%) | 5.9 |

### Traffic

| Age (year) | Heavy Trucks (cumulative) |
|---|---|
| 2016 (initial) | 2,932 |
| 2026 (10 years) | 4,529,990 |
| 2036 (20 years) | 9,435,710 |

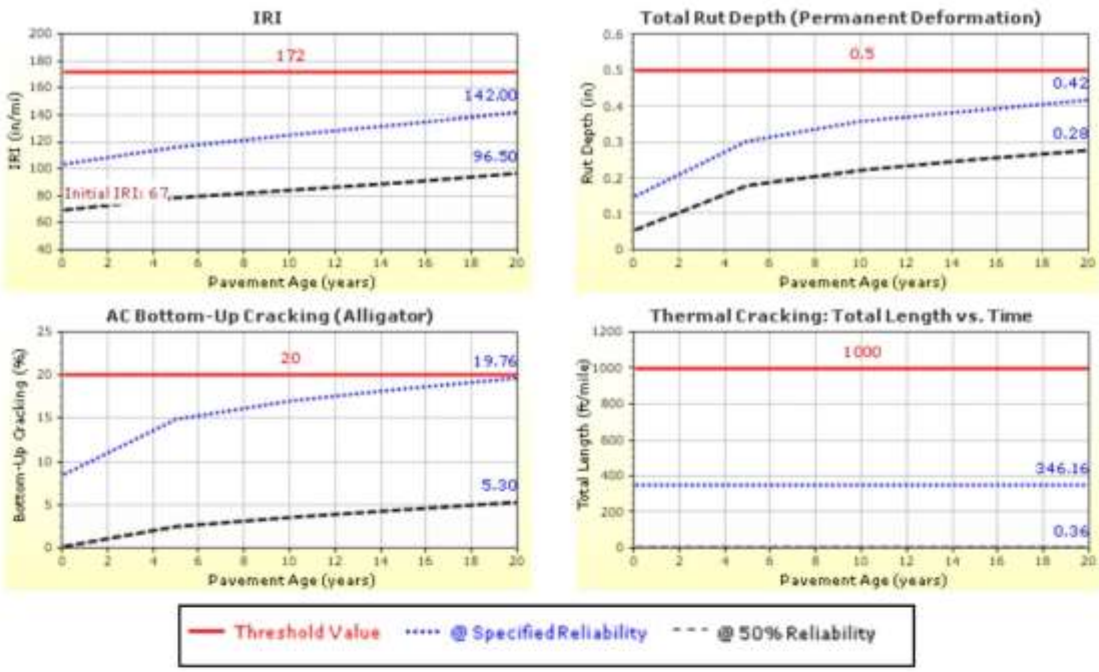
## Design Outputs

### Distress Prediction Summary

| Distress Type | Distress @ Specified Reliability | | Reliability (%) | | Criterion Satisfied? |
|---|---|---|---|---|---|
| | Target | Predicted | Target | Achieved | |
| Terminal IRI (in/mile) | 172.00 | 142.02 | 95.00 | 99.68 | Pass |
| Permanent deformation - total pavement (in) | 0.50 | 0.42 | 95.00 | 99.52 | Pass |
| AC bottom-up fatigue cracking (% lane area) | 20.00 | 19.76 | 95.00 | 95.27 | Pass |
| AC thermal cracking (ft/mile) | 1000.00 | 346.16 | 95.00 | 100.00 | Pass |
| AC top-down fatigue cracking (ft/mile) | 2000.00 | 1100.37 | 95.00 | 99.99 | Pass |
| Permanent deformation - AC only (in) | 0.50 | 0.40 | 95.00 | 99.82 | Pass |

Report generated on: 12/2/2019 5:28 PM | Version: 2.3.0+65 | Created by: J Schenkel on: 9/4/2014 12:00 AM | Approved by: on: 1/1/0001 12:00 AM | Page 1 of 24

## Distress Charts



# JN 88876 & 90076 & 90077 - HMA(1)

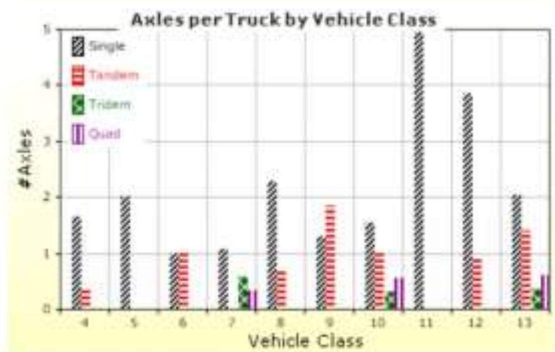
File Name: C:\Users\schenkelj\Documents\My ME Design\My ME Design\JN 88876 & 90076 & 90077 - HMA(1).dgpx

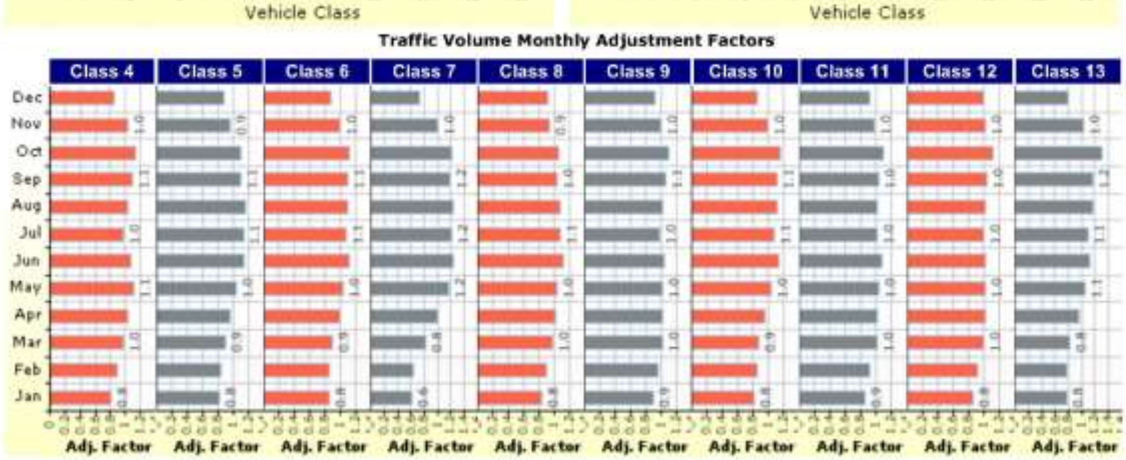
## Traffic Inputs

### Graphical Representation of Traffic Inputs

| | | | |
|---|---|---|---|
| Initial two-way AADTT: | 2,932 | Percent of trucks in design direction (%): | 51.0 |
| Number of lanes in design direction: | 2 | Percent of trucks in design lane (%): | 80.0 |
| | | Operational speed (mph) | 55.0 |



## Tabular Representation of Traffic Inputs

### Volume Monthly Adjustment Factors

Level 3: Default MAF

| Month | Vehicle Class | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| January | 0.8 | 0.8 | 0.8 | 0.6 | 0.8 | 0.9 | 0.8 | 0.9 | 0.8 | 0.8 |
| February | 0.9 | 0.8 | 0.9 | 0.6 | 0.9 | 0.9 | 0.8 | 0.9 | 0.9 | 0.8 |
| March | 1.0 | 0.9 | 0.9 | 0.8 | 1.0 | 1.0 | 0.9 | 1.0 | 1.0 | 0.8 |
| April | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 |
| May | 1.1 | 1.0 | 1.0 | 1.2 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.1 |
| June | 1.1 | 1.1 | 1.1 | 1.2 | 1.1 | 1.0 | 1.1 | 1.1 | 1.0 | 1.1 |
| July | 1.0 | 1.1 | 1.1 | 1.2 | 1.1 | 1.0 | 1.1 | 1.0 | 1.0 | 1.1 |
| August | 1.0 | 1.2 | 1.1 | 1.2 | 1.1 | 1.0 | 1.1 | 1.0 | 1.0 | 1.2 |
| September | 1.1 | 1.1 | 1.1 | 1.2 | 1.0 | 1.1 | 1.1 | 1.0 | 1.0 | 1.2 |
| October | 1.1 | 1.1 | 1.1 | 1.2 | 1.1 | 1.1 | 1.2 | 1.1 | 1.1 | 1.3 |
| November | 1.0 | 0.9 | 1.0 | 1.0 | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| December | 0.8 | 0.9 | 0.9 | 0.7 | 0.9 | 0.9 | 0.9 | 0.9 | 1.0 | 0.8 |

### Distributions by Vehicle Class

| Vehicle Class | AADTT Distribution (%) (Level 3) | Growth Factor | |
|---|---|---|---|
| | | Rate (%) | Function |
| Class 4 | 1.78% | 0.8% | Compound |
| Class 5 | 11.5% | 0.8% | Compound |
| Class 6 | 9.17% | 0.8% | Compound |
| Class 7 | 1.4% | 0.8% | Compound |
| Class 8 | 8.62% | 0.8% | Compound |
| Class 9 | 33.77% | 0.8% | Compound |
| Class 10 | 12.96% | 0.8% | Compound |
| Class 11 | 2.21% | 0.8% | Compound |
| Class 12 | 1.97% | 0.8% | Compound |
| Class 13 | 16.62% | 0.8% | Compound |

### Truck Distribution by Hour does not apply

### Axle Configuration

| Traffic Wander | |
|---|---|
| Mean wheel location (in) | 18.0 |
| Traffic wander standard deviation (in) | 10.0 |
| Design lane width (ft) | 12.0 |

| Axle Configuration | |
|---|---|
| Average axle width (ft) | 8.5 |
| Dual tire spacing (in) | 12.0 |
| Tire pressure (psi) | 120.0 |

| Average Axle Spacing | |
|---|---|
| Tandem axle spacing (in) | 51.6 |
| Tridem axle spacing (in) | 49.2 |
| Quad axle spacing (in) | 49.2 |

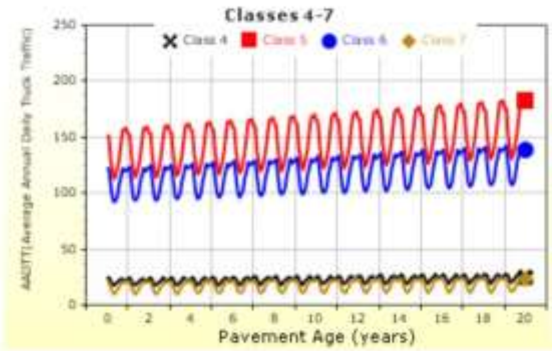
Wheelbase does not apply

### Number of Axles per Truck

| Vehicle Class | Single Axle | Tandem Axle | Tridem Axle | Quad Axle |
|---|---|---|---|---|
| Class 4 | 1.65 | 0.36 | 0 | 0 |
| Class 5 | 2 | 0.05 | 0 | 0 |
| Class 6 | 1 | 1 | 0 | 0 |
| Class 7 | 1.06 | 0.06 | 0.59 | 0.35 |
| Class 8 | 2.28 | 0.74 | 0 | 0 |
| Class 9 | 1.29 | 1.85 | 0 | 0 |
| Class 10 | 1.54 | 1 | 0.31 | 0.56 |
| Class 11 | 4.99 | 0 | 0 | 0 |
| Class 12 | 3.85 | 0.96 | 0 | 0 |
| Class 13 | 2.03 | 1.4 | 0.36 | 0.61 |

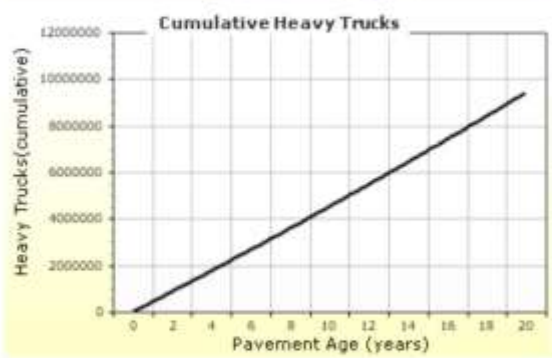
## AADTT (Average Annual Daily Truck Traffic) Growth

* Traffic cap is not enforced





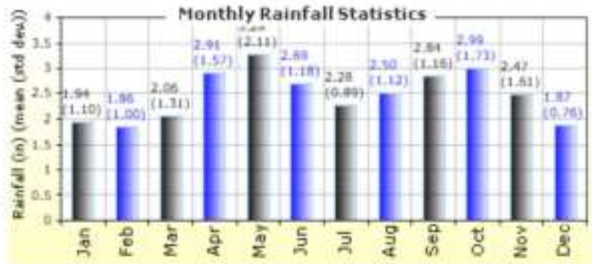




## Climate Inputs

### Climate Data Sources:

| Climate Station Cities: | Location (lat lon elevation(ft)) |
|---|---|
| MUSKEGON, MI | 43.17100 -86.23700 626 |

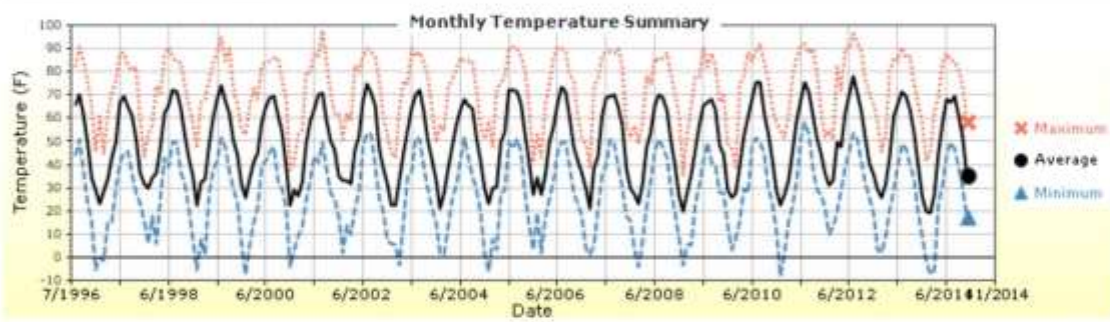


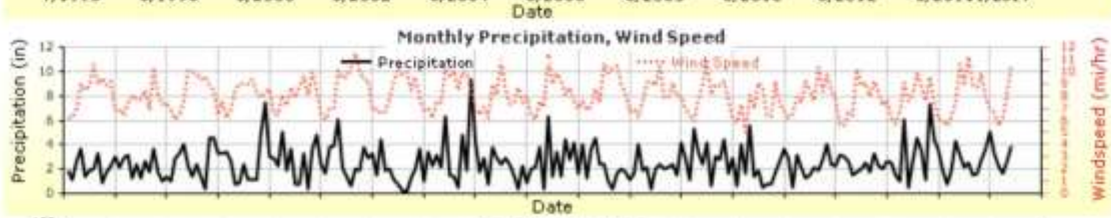

### Annual Statistics:

| | |
|---|---|
| Mean annual air temperature (ºF) | 49.30 |
| Mean annual precipitation (in) | 29.70 |
| Freezing index (ºF - days) | 603.67 |
| Average annual number of freeze/thaw cycles: | 57.77 |

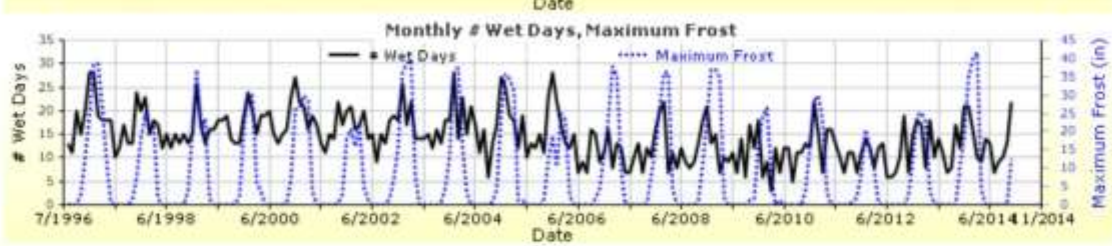
Water table depth (ft) 5.00

### Monthly Climate Summary:

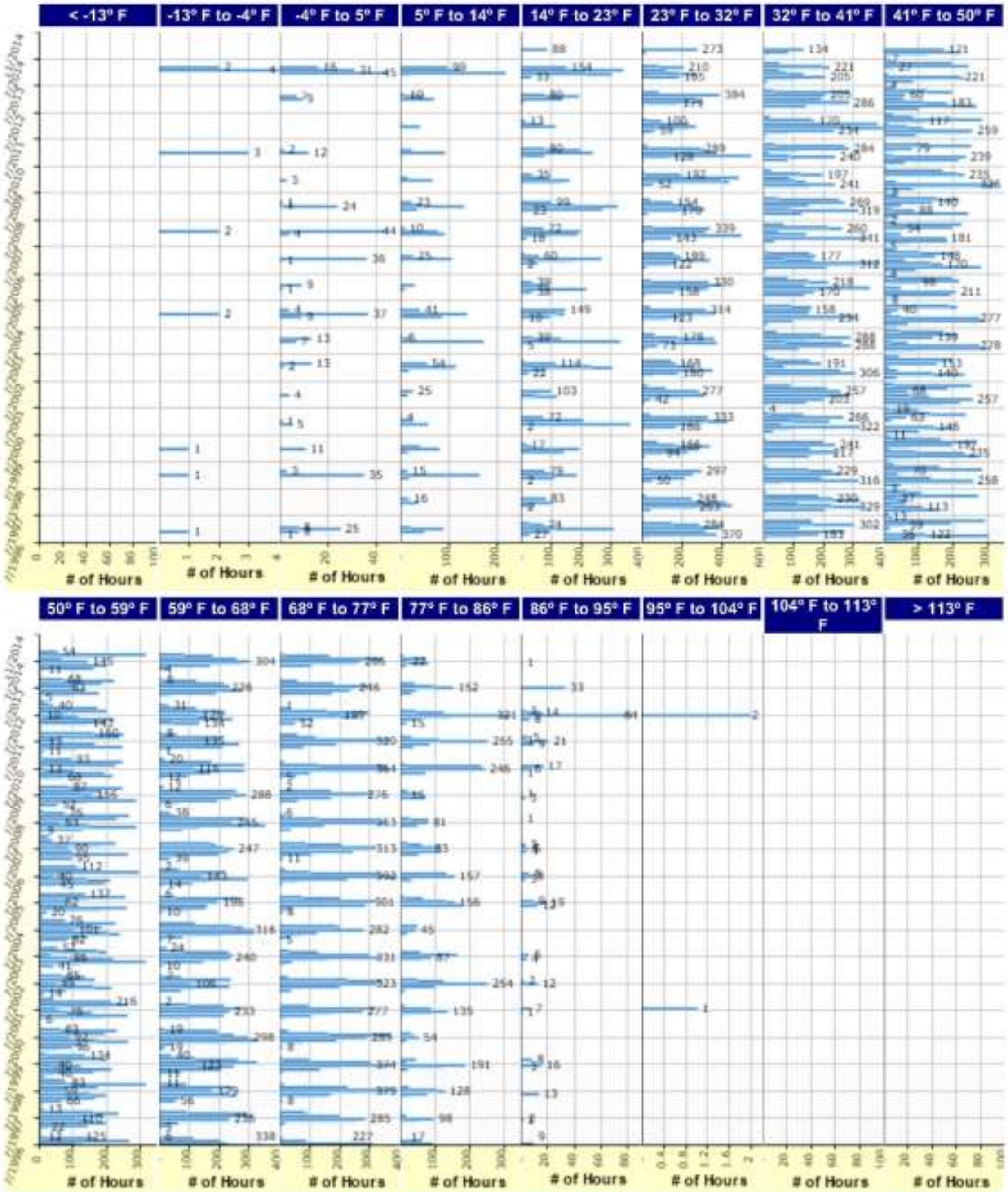






## Hourly Air Temperature Distribution by Month:



# Design Properties

## HMA Design Properties

| | |
|---|---|
| **Use Multilayer Rutting Model** | False |
| **Using G* based model (not nationally calibrated)** | False |
| **Is NCHRP 1-37A HMA Rutting Model Coefficients** | True |
| **Endurance Limit** | - |
| **Use Reflective Cracking** | True |

| **Structure - ICM Properties** | |
|---|---|
| AC surface shortwave absorptivity | 0.85 |

| Layer Name | Layer Type | Interface Friction |
|---|---|---|
| Layer 1 Flexible : 5E10_TopCourse | Flexible (1) | 1.00 |
| Layer 2 Flexible : 3E10 Leveling Course | Flexible (1) | 1.00 |
| Layer 3 Flexible : 3E10_BaseCourse | Flexible (1) | 1.00 |
| Layer 4 Non-stabilized Base : OGDC | Non-stabilized Base (4) | 1.00 |
| Layer 5 Non-stabilized Base : Sand Subbase | Non-stabilized Base (4) | 1.00 |
| Layer 6 Subgrade : Poorly Graded Sand/Silty Sand Subgrade | Subgrade (5) | - |

## Thermal Cracking (Input Level: 1)

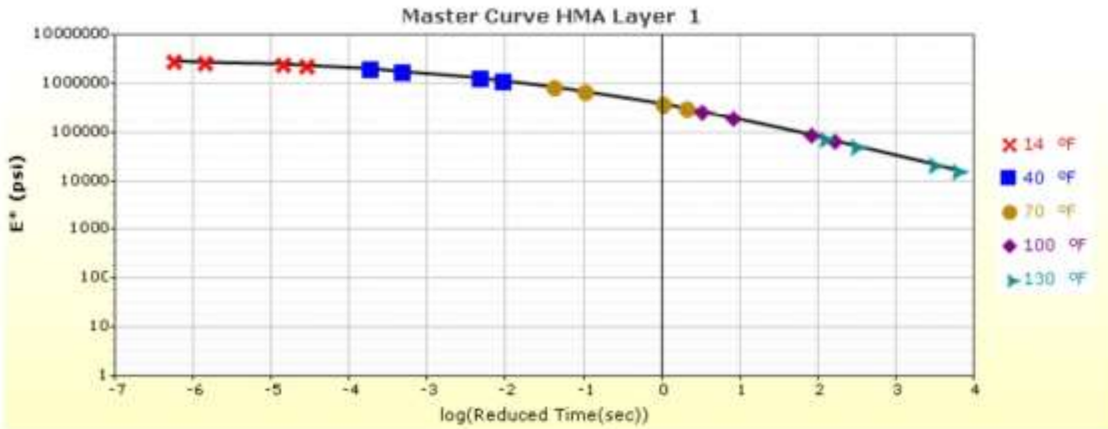
| | |
|---|---|
| **Indirect tensile strength at 14 ºF (psi)** | 533.00 |
| **Thermal Contraction** | |
| Is thermal contraction calculated? | True |
| Mix coefficient of thermal contraction (in/in/ºF) | - |
| Aggregate coefficient of thermal contraction (in/in/ºF) | 5.0e-006 |
| Voids in Mineral Aggregate (%) | 18.0 |

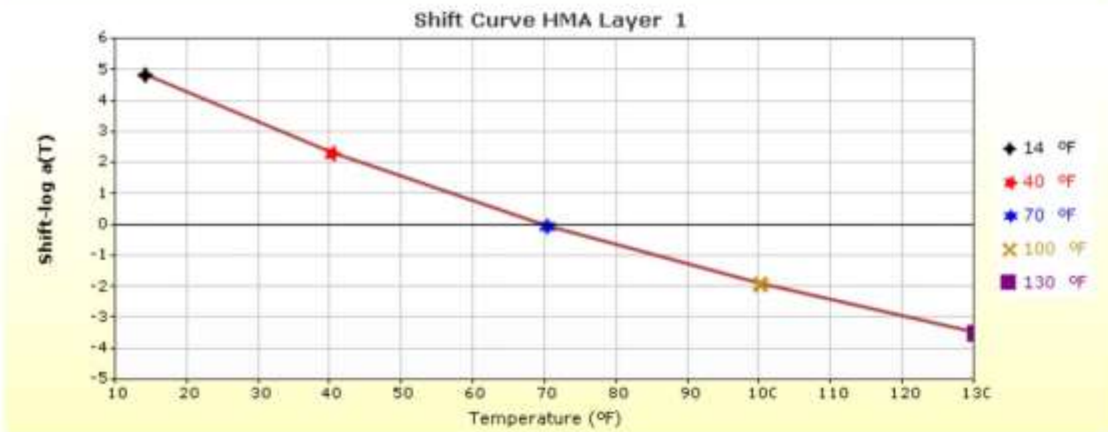
| | Creep Compliance (1/psi) | | |
|---|---|---|---|
| **Loading time (sec)** | **-4 ºF** | **14 ºF** | **32 ºF** |
| 1 | 3.30e-007 | 4.29e-007 | 6.46e-007 |
| 2 | 3.42e-007 | 4.57e-007 | 7.15e-007 |
| 5 | 3.60e-007 | 5.00e-007 | 8.25e-007 |
| 10 | 3.76e-007 | 5.40e-007 | 9.31e-007 |
| 20 | 3.95e-007 | 5.87e-007 | 1.06e-006 |
| 50 | 4.25e-007 | 6.64e-007 | 1.28e-006 |
| 100 | 4.52e-007 | 7.35e-007 | 1.49e-006 |

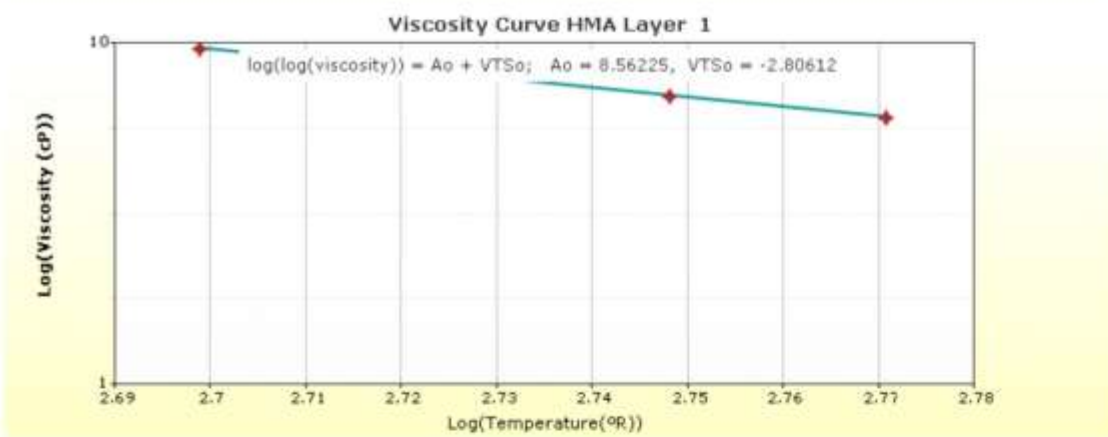
# JN 88876 & 90076 & 90077 - HMA(1)

File Name: C:\Users\schenkelj\Documents\My ME Design\My ME Design\JN 88876 & 90076 & 90077 - HMA(1).dgpx

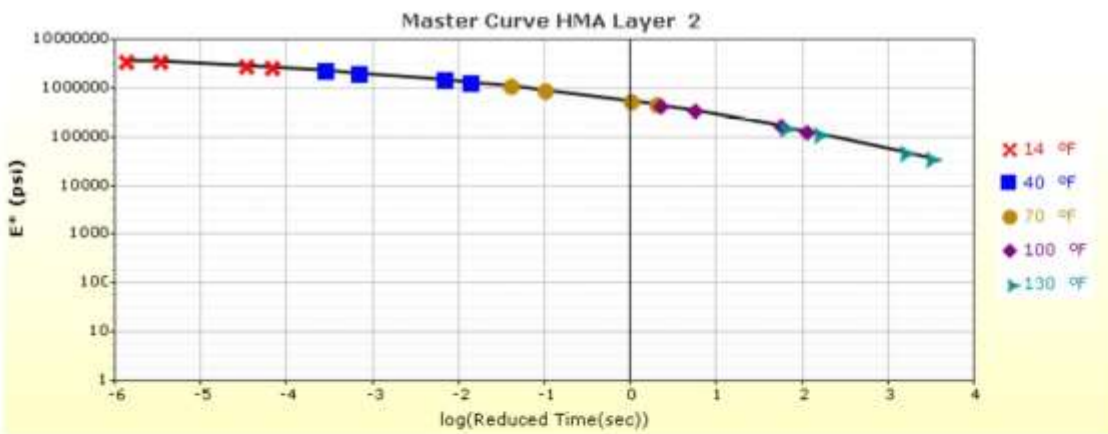
## HMA Layer 1: Layer 1 Flexible : 5E10_TopCourse



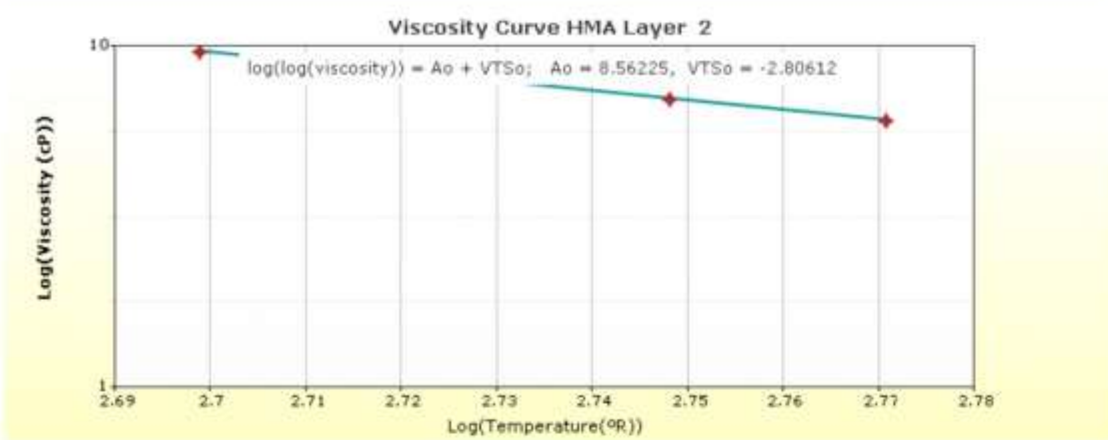



## HMA Layer 2: Layer 2 Flexible : 3E10 Leveling Course



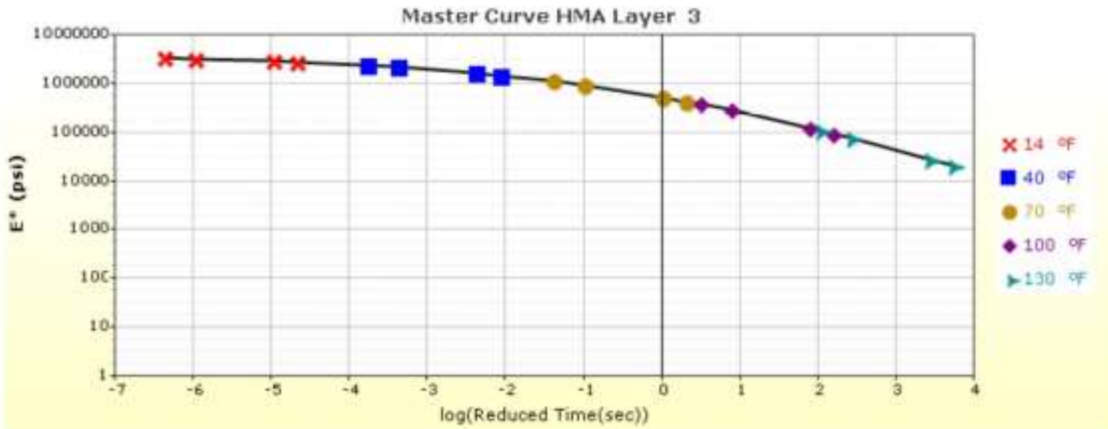


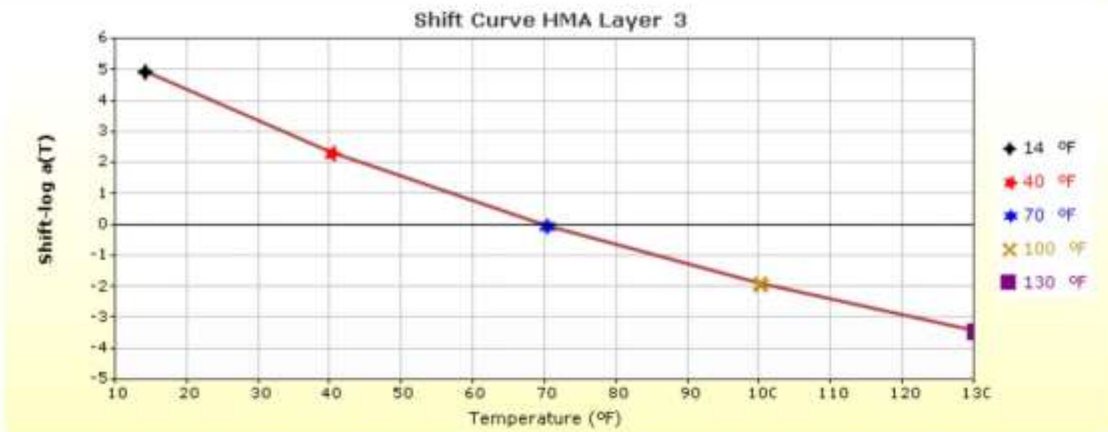


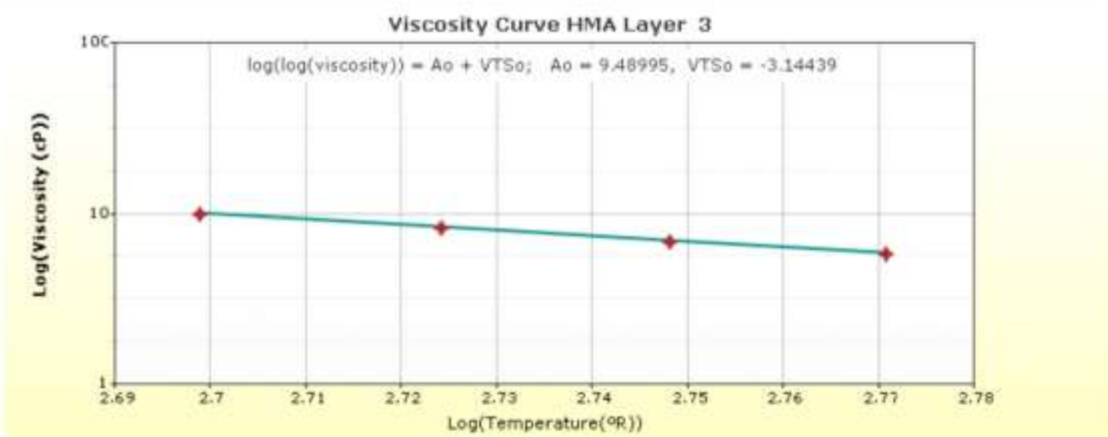
JN 88876 & 90076 & 90077 - HMA(1)

File Name: C:\Users\schenkelj\Documents\My ME Design\My ME Design\JN 88876 & 90076 & 90077 - HMA(1).dgpx

**HMA Layer 3: Layer 3 Flexible : 3E10_BaseCourse**



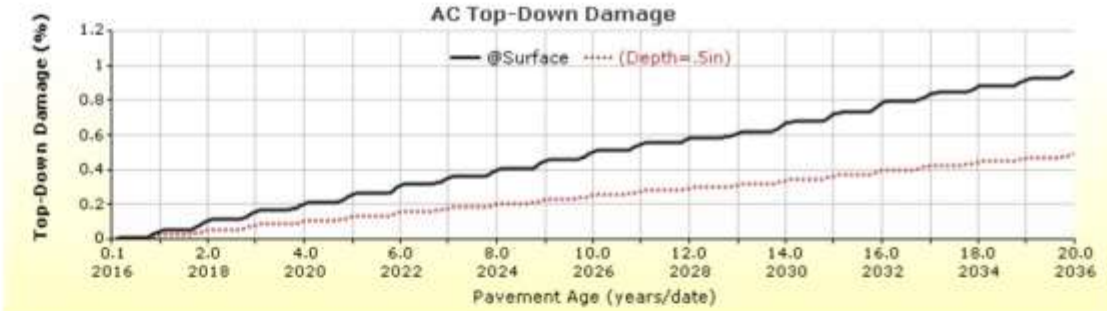

Report generated on: 12/2/2019 5:28 PM | Version: 2.3.0+65 | Created by: J Schenkel on: 9/4/2014 12:00 AM | Approved by: on: 1/1/0001 12:00 AM | Page 12 of 24

## Analysis Output Charts

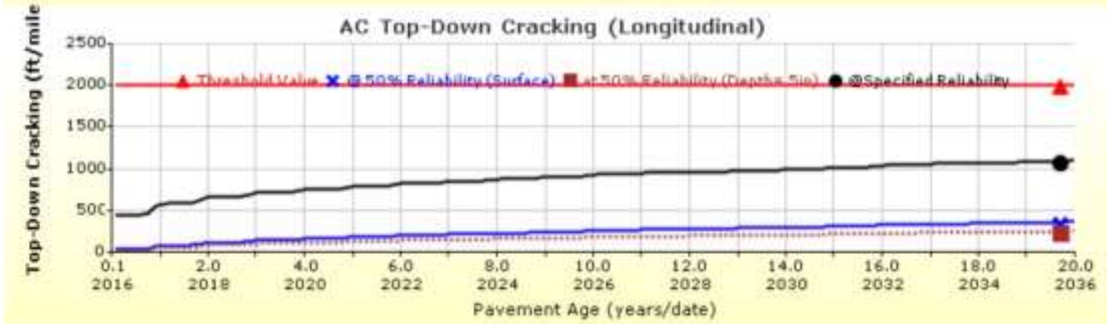


# JN 88876 & 90076 & 90077 - HMA(1)

File Name: C:\Users\schenkelj\Documents\My ME Design\My ME Design\JN 88876 & 90076 & 90077 - HMA(1).dgpx









Report generated on: 12/2/2019 5:28 PM

Version: 2.3.0+65

Created by: J Schenkel on: 9/4/2014 12:00 AM

Approved by: on: 1/1/0001 12:00 AM

# JN 88876 & 90076 & 90077 - HMA(1)

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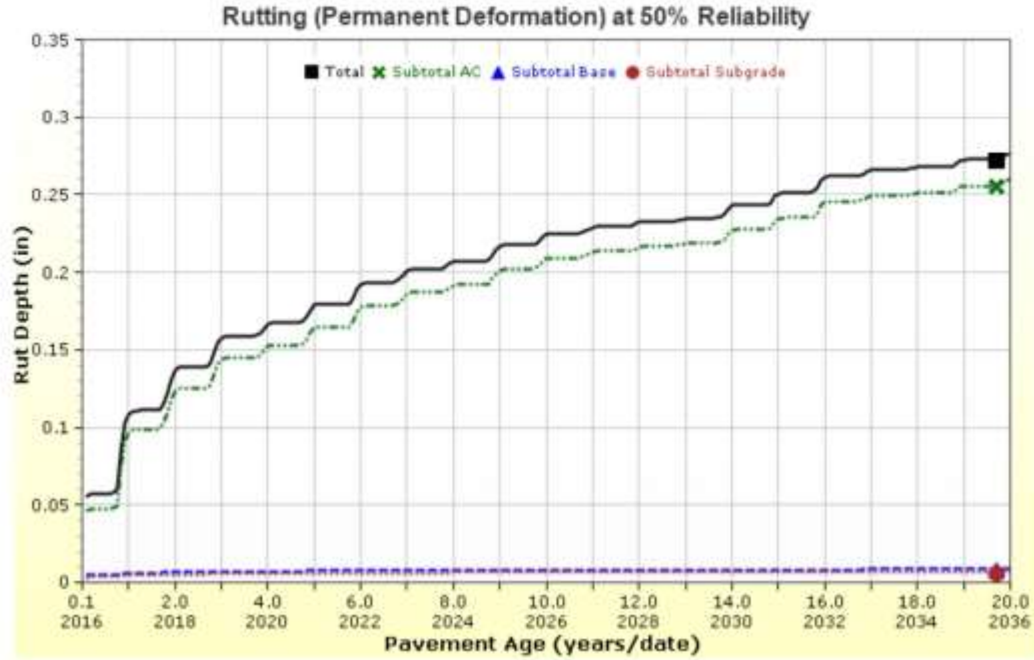
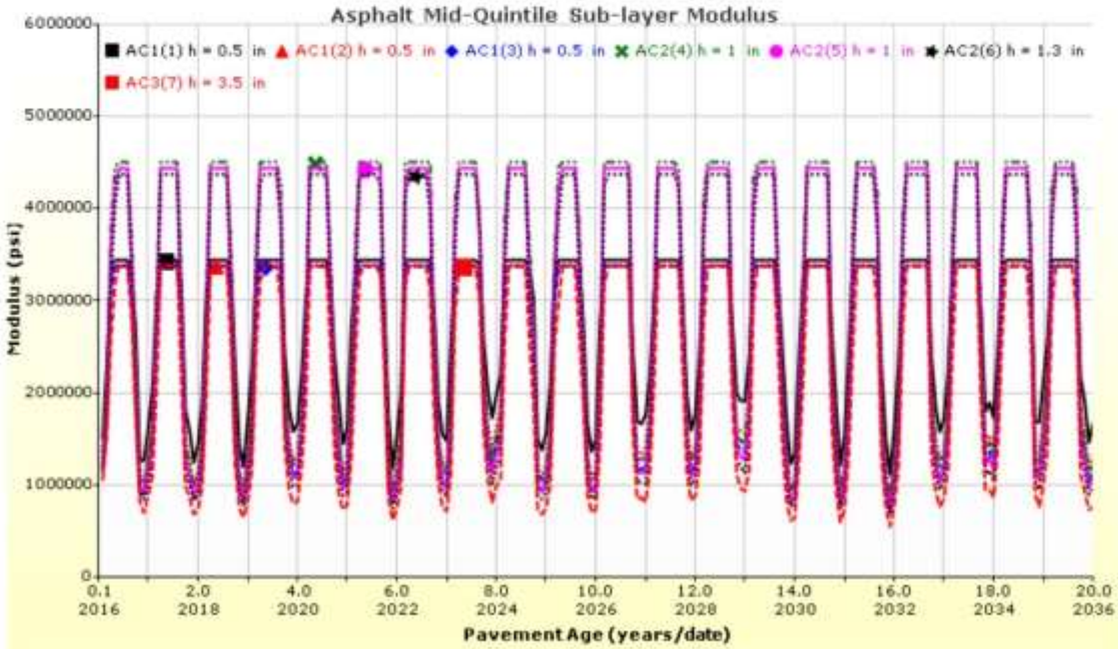
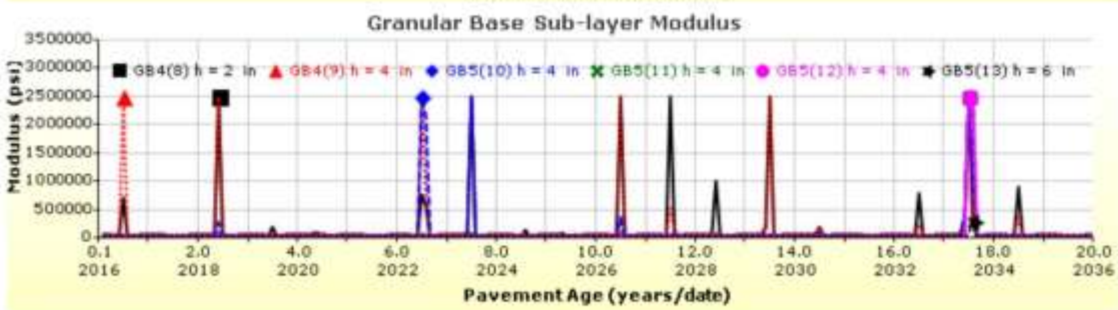



Report generated on: 12/2/2019 5:28 PM | Version: 2.3.0+65 | Created by: J Schenkel on: 9/4/2014 12:00 AM | Approved by: on: 1/1/0001 12:00 AM | Page 15 of 24

# JN 88876 & 90076 & 90077 - HMA(1)

File Name: C:\Users\schenkelj\Documents\My ME Design\My ME Design\JN 88876 & 90076 & 90077 - HMA(1).dgpx





Report generated on: 12/2/2019 5:28 PM

Version: 2.3.0+65

Created by: J Schenkel on: 9/4/2014 12:00 AM

Approved by: on: 1/1/0001 12:00 AM

Page 16 of 24

# Layer Information

## Layer 1 Flexible : 5E10_TopCourse

| Asphalt | | | |
|---|---|---|---|
| Thickness (in) | 1.5 | | |
| Unit weight (pcf) | 145.9 | | |
| Poisson's ratio | Is Calculated? | False | |
| | Ratio | 0.35 | |
| | Parameter A | - | |
| | Parameter B | - | |

### Asphalt Dynamic Modulus (Input Level: 1)

| T (°F) | 0.1 Hz | 1 Hz | 10 Hz | 25 Hz |
|---|---|---|---|---|
| 14 | 1943087.2 | 2425736 | 2844513 | 2989406.3 |
| 40 | 831277.6 | 1289174.2 | 1795463.6 | 1996816.3 |
| 70 | 190407.1 | 392031.7 | 713565.4 | 874245.7 |
| 100 | 37177.6 | 89352.8 | 202149.3 | 272283.2 |
| 130 | 9706.2 | 22837.8 | 55389.1 | 78407.4 |

### Asphalt Binder

| Temperature (°F) | Binder Gstar (Pa) | Phase angle (deg) |
|---|---|---|
| 40 | 9799661 | 52.2 |
| 70 | 1439853.3 | 59.9 |
| 100 | 122051.7 | 66.3 |
| 130 | 10313.5 | 71.2 |
| 168 | 975.2 | 75.5 |

### General Info

| Name | Value |
|---|---|
| Reference temperature (°F) | 70 |
| Effective binder content (%) | 12.1 |
| Air voids (%) | 5.9 |
| Thermal conductivity (BTU/hr-ft-°F) | 0.67 |
| Heat capacity (BTU/lb-°F) | 0.23 |

### Identifiers

| Field | Value |
|---|---|
| Display name/identifier | 5E10_TopCourse |
| Description of object | |
| Author | |
| Date Created | 1/1/0001 12:00:00AM |
| Approver | |
| Date approved | 1/1/0001 12:00:00AM |
| State | |
| District | |
| County | |
| Highway | |
| Direction of Travel | |
| From station (miles) | |
| To station (miles) | |
| Province | |
| User defined field 1 | 64-28 |
| User defined field 2 | Used [test] for E/IDT/Dt |
| User defined field 3 | |
| Revision Number | 0 |

## Layer 2 Flexible : 3E10 Leveling Course

| Asphalt | | |
|---|---|---|
| Thickness (in) | 3.3 | |
| Unit weight (pcf) | 147.0 | |
| Poisson's ratio | Is Calculated? | False |
| | Ratio | 0.35 |
| | Parameter A | - |
| | Parameter B | - |

### Asphalt Dynamic Modulus (Input Level: 1)

| T (°F) | 0.1 Hz | 1 Hz | 10 Hz | 25 Hz |
|---|---|---|---|---|
| 14 | 2183019.6 | 2851377.1 | 3547748.4 | 3827553.9 |
| 40 | 1003126.4 | 1513282.9 | 2116245.9 | 2375405.7 |
| 70 | 302830.1 | 567419.3 | 951021.3 | 1136486.9 |
| 100 | 74014.2 | 171167.8 | 352302.2 | 453942.8 |
| 130 | 19285.1 | 50040.9 | 120860.3 | 166767.2 |

### Asphalt Binder

| Temperature (°F) | Binder Gstar (Pa) | Phase angle (deg) |
|---|---|---|
| 40 | 9799661 | 52.2 |
| 70 | 1439853.3 | 59.9 |
| 100 | 122051.7 | 66.3 |
| 130 | 10313.5 | 71.2 |
| 168 | 975.2 | 75.5 |

### General Info

| Name | Value |
|---|---|
| Reference temperature (°F) | 70 |
| Effective binder content (%) | 11.1 |
| Air voids (%) | 6 |
| Thermal conductivity (BTU/hr-ft-°F) | 0.67 |
| Heat capacity (BTU/lb-°F) | 0.23 |

### Identifiers

| Field | Value |
|---|---|
| Display name/identifier | 3E10 Leveling Course |
| Description of object | PG 64-28 |
| Author | |
| Date Created | 1/1/0001 12:00:00AM |
| Approver | |
| Date approved | 1/1/0001 12:00:00AM |
| State | |
| District | |
| County | |
| Highway | |
| Direction of Travel | |
| From station (miles) | |
| To station (miles) | |
| Province | |
| User defined field 1 | Pred |
| User defined field 2 | |
| User defined field 3 | |
| Revision Number | 0 |

## Layer 3 Flexible : 3E10_BaseCourse

| Asphalt | | |
|---|---|---|
| Thickness (in) | 3.5 | |
| Unit weight (pcf) | 147.5 | |
| Poisson's ratio | Is Calculated? | False |
| | Ratio | 0.35 |
| | Parameter A | - |
| | Parameter B | - |

### Asphalt Dynamic Modulus (Input Level: 1)

| T (°F) | 0.1 Hz | 1 Hz | 10 Hz | 25 Hz |
|---|---|---|---|---|
| 14 | 2243734.6 | 2802663.1 | 3282096.1 | 3446574.1 |
| 40 | 1031882.6 | 1587640.8 | 2184713.3 | 2417188.8 |
| 70 | 257740.6 | 531544.1 | 953697 | 1158550.6 |
| 100 | 49260.7 | 124367.9 | 286430 | 385695.4 |
| 130 | 10848.1 | 28150.1 | 73307 | 105825.6 |

### Asphalt Binder

| Temperature (°F) | Binder Gstar (Pa) | Phase angle (deg) |
|---|---|---|
| 40 | 11843112.7 | 47.3 |
| 70 | 2023700.3 | 59.7 |
| 100 | 155618.5 | 70.2 |
| 130 | 9667.5 | 78.3 |
| 168 | 610.5 | 84.8 |

### General Info

| Name | Value |
|---|---|
| Reference temperature (°F) | 70 |
| Effective binder content (%) | 10.4 |
| Air voids (%) | 5.7 |
| Thermal conductivity (BTU/hr-ft-°F) | 0.67 |
| Heat capacity (BTU/lb-°F) | 0.23 |

### Identifiers

| Field | Value |
|---|---|
| Display name/identifier | 3E10_BaseCourse |
| Description of object | |
| Author | |
| Date Created | 1/1/0001 12:00:00AM |
| Approver | |
| Date approved | 1/1/0001 12:00:00AM |
| State | |
| District | |
| County | |
| Highway | |
| Direction of Travel | |
| From station (miles) | |
| To station (miles) | |
| Province | |
| User defined field 1 | 58-22 |
| User defined field 2 | Used [test] for E/IDT/Dt |
| User defined field 3 | |
| Revision Number | 0 |

## Layer 4 Non-stabilized Base : OGDC

| Unbound | |
|---|---|
| Layer thickness (in) | 6.0 |
| Poisson's ratio | 0.35 |
| Coefficient of lateral earth pressure (k0) | 0.5 |

### Modulus (Input Level: 2)

| | |
|---|---|
| **Analysis Type:** | Modify input values by temperature/moisture |
| **Method:** | Resilient Modulus (psi) |

| Resilient Modulus (psi) |
|---|
| 33000.0 |

| | |
|---|---|
| **Use Correction factor for NDT modulus?** | - |
| **NDT Correction Factor:** | - |

### Identifiers

| Field | Value |
|---|---|
| Display name/identifier | OGDC |
| Description of object | |
| Author | |
| Date Created | 1/1/0001 12:00:00AM |
| Approver | |
| Date approved | 1/1/0001 12:00:00AM |
| State | |
| District | |
| County | |
| Highway | |
| Direction of Travel | |
| From station (miles) | |
| To station (miles) | |
| Province | |
| User defined field 1 | |
| User defined field 2 | |
| User defined field 3 | |
| Revision Number | 0 |

### Sieve

| | |
|---|---|
| **Liquid Limit** | 0.0 |
| **Plasticity Index** | 0.0 |
| **Is layer compacted?** | True |

| | Is User Defined? | Value |
|---|---|---|
| Maximum dry unit weight (pcf) | False | 127 |
| Saturated hydraulic conductivity (ft/hr) | False | 4.322e-01 |
| Specific gravity of solids | False | 2.7 |
| Water Content (%) | False | 6.5 |

| User-defined Soil Water Characteristic Curve (SWCC) | |
|---|---|
| Is User Defined? | False |
| af | 9.6111 |
| bf | 2.9560 |
| cf | 0.8456 |
| hr | 100.0000 |

| Sieve Size | % Passing |
|---|---|
| 0.001mm | |
| 0.002mm | |
| 0.020mm | |
| #200 | 4.2 |
| #100 | |
| #80 | |
| #60 | |
| #50 | |
| #40 | |
| #30 | 13.7 |
| #20 | |
| #16 | |
| #10 | |
| #8 | 23.6 |
| #4 | |
| 3/8-in. | |
| 1/2-in. | 58.8 |
| 3/4-in. | |
| 1-in. | 93.5 |
| 1 1/2-in. | 100.0 |
| 2-in. | |
| 2 1/2-in. | |
| 3-in. | |
| 3 1/2-in. | |

## Layer 5 Non-stabilized Base : Sand Subbase

| Unbound | |
|---|---|
| Layer thickness (in) | 18.0 |
| Poisson's ratio | 0.35 |
| Coefficient of lateral earth pressure (k0) | 0.5 |

### Modulus (Input Level: 3)

| | |
|---|---|
| **Analysis Type:** | Modify input values by temperature/moisture |
| **Method:** | Resilient Modulus (psi) |

| Resilient Modulus (psi) |
|---|
| 20000.0 |

| | |
|---|---|
| **Use Correction factor for NDT modulus?** | - |
| **NDT Correction Factor:** | - |

### Identifiers

| Field | Value |
|---|---|
| Display name/identifier | Sand Subbase |
| Description of object | |
| Author | |
| Date Created | 1/1/0001 12:00:00AM |
| Approver | |
| Date approved | 1/1/0001 12:00:00AM |
| State | |
| District | |
| County | |
| Highway | |
| Direction of Travel | |
| From station (miles) | |
| To station (miles) | |
| Province | |
| User defined field 1 | |
| User defined field 2 | |
| User defined field 3 | |
| Revision Number | 0 |

### Sieve

| | |
|---|---|
| **Liquid Limit** | 0.0 |
| **Plasticity Index** | 0.0 |
| **Is layer compacted?** | True |

| | Is User Defined? | Value |
|---|---|---|
| Maximum dry unit weight (pcf) | False | 124.6 |
| Saturated hydraulic conductivity (ft/hr) | False | 9.427e-03 |
| Specific gravity of solids | False | 2.7 |
| Water Content (%) | False | 9.5 |

| User-defined Soil Water Characteristic Curve (SWCC) | |
|---|---|
| Is User Defined? | False |
| af | 5.4729 |
| bf | 1.9212 |
| cf | 0.8511 |
| hr | 100.0000 |

| Sieve Size | % Passing |
|---|---|
| 0.001mm | |
| 0.002mm | |
| 0.020mm | |
| #200 | 4.6 |
| #100 | 15.6 |
| #80 | |
| #60 | |
| #50 | |
| #40 | |
| #30 | |
| #20 | |
| #16 | |
| #10 | |
| #8 | |
| #4 | |
| 3/8-in. | |
| 1/2-in. | |
| 3/4-in. | |
| 1-in. | 99.8 |
| 1 1/2-in. | |
| 2-in. | |
| 2 1/2-in. | |
| 3-in. | |
| 3 1/2-in. | |

## Layer 6 Subgrade : Poorly Graded Sand/Silty Sand Subgrade

| **Unbound** | |
|---|---|
| Layer thickness (in) | Semi-infinite |
| Poisson's ratio | 0.35 |
| Coefficient of lateral earth pressure (k0) | 0.5 |

### Modulus (Input Level: 3)

| | |
|---|---|
| **Analysis Type:** | Annual representative values |
| **Method:** | Resilient Modulus (psi) |

| **Resilient Modulus (psi)** |
|---|
| 7000.0 |

| | |
|---|---|
| **Use Correction factor for NDT modulus?** | - |
| **NDT Correction Factor:** | - |

### Identifiers

| **Field** | **Value** |
|---|---|
| Display name/identifier | Poorly Graded Sand/Silty Sand |
| Description of object | |
| Author | |
| Date Created | 6/20/2014 12:00:00AM |
| Approver | |
| Date approved | 1/1/0001 12:00:00AM |
| State | |
| District | |
| County | |
| Highway | |
| Direction of Travel | |
| From station (miles) | |
| To station (miles) | |
| Province | |
| User defined field 1 | |
| User defined field 2 | |
| User defined field 3 | |
| Revision Number | 0 |

### Sieve

| | |
|---|---|
| **Liquid Limit** | 15.5 |
| **Plasticity Index** | 5.0 |
| **Is layer compacted?** | True |

| | **Is User Defined?** | **Value** |
|---|---|---|
| Maximum dry unit weight (pcf) | True | 113.8 |
| Saturated hydraulic conductivity (ft/hr) | False | 1.938e-03 |
| Specific gravity of solids | False | 2.7 |
| Water Content (%) | False | 8.7 |

| **User-defined Soil Water Characteristic Curve (SWCC)** | |
|---|---|
| **Is User Defined?** | False |
| **af** | 4.0786 |
| **bf** | 2.2975 |
| **cf** | 0.9252 |
| **hr** | 166.1000 |

| **Sieve Size** | **% Passing** |
|---|---|
| 0.001mm | |
| 0.002mm | |
| 0.020mm | |
| #200 | 6.6 |
| #100 | 17.5 |
| #80 | |
| #60 | |
| #50 | |
| #40 | 66.1 |
| #30 | |
| #20 | 79.4 |
| #16 | |
| #10 | 87.2 |
| #8 | |
| #4 | 92.5 |
| 3/8-in. | 96.3 |
| 1/2-in. | |
| 3/4-in. | |
| 1-in. | |
| 1 1/2-in. | |
| 2-in. | |
| 2 1/2-in. | |
| 3-in. | |
| 3 1/2-in. | |

## Calibration Coefficients

### AC Fatigue

| AC Fatigue | |
|---|---|
| $N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$ | k1: 0.007566 |
| | k2: 3.9492 |
| $C = 10^M$ | k3: 1.281 |
| | Bf1: 1 |
| $M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$ | Bf2: 1 |
| | Bf3: 1 |

### AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1} T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$$

$$C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$$

*Where:*

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain(^{in}/_{in})$
$\varepsilon_r = resilient\ strain(^{in}/_{in})$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

| | | |
|---|---|---|
| **AC Rutting Standard Deviation** | 0.1126*Pow(RUT,0.2352) | |
| AC Layer | K1:-3.35412 K2:1.5606 K3:0.4791 | Br1:0.9453 Br2:1.3 Br3:0.7 |

### Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f$ = observed amount of thermal cracking(ft/500ft)
$k$ = refression coefficient determined through field calibration
$N()$ = standard normal distribution evaluated at( )
$\sigma$ = standard deviation of the log of the depth of cracks in the pavements
$C$ = crack depth(in)
$h_{ac}$ = thickness of asphalt layer(in)
$\Delta C$ = Change in the crack depth due to a cooling cycle
$\Delta K$ = Change in the stress intensity factor due to a cooling cycle
$A, n$ = Fracture parameters for the asphalt mixture
$E$ = mixture stiffness
$\sigma_M$ = Undamaged mixture tensile strength
$\beta_t$ = Calibration parameter

| | |
|---|---|
| Level 1 K: 0.75 | Level 1 Standard Deviation: 0.4258 * THERMAL + 210.08 |
| Level 2 K: 0.5 | Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462 |
| Level 3 K: 4 | Level 3 Standard Deviation: 0.7737 * THERMAL + 622.92 |

### CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

| | | | |
|---|---|---|---|
| k1: 1 | k2: 1 | Bc1: 1 | Bc2:1 |

| Subgrade Rutting | | | |
|---|---|---|---|
| $\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left\| e^{-\left(\frac{\rho}{N}\right)^\beta} \right\|$ | | $\delta_a$ = permanent deformation for the layer<br>$N$ = number of repetitions<br>$\varepsilon_v$ = average veritcal strain(in/in)<br>$\varepsilon_0, \beta, \rho$ = material properties<br>$\varepsilon_r$ = resilient strain(in/in) | |
| **Granular** | | **Fine** | |
| k1: 2.03 | Bs1: 0.0985 | k1: 1.35 | Bs1: 0.0367 |
| Standard Deviation (BASERUT)<br>0.1145*Pow(BASERUT,0.3907) | | Standard Deviation (BASERUT)<br>3.6118*Pow(SUBRUT,1.0951) | |

| AC Cracking | | | | | | |
|---|---|---|---|---|---|---|
| **AC Top Down Cracking** | | | | **AC Bottom Up Cracking** | | |
| $FC_{top} = \left(\frac{C_4}{1+e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$ | | | | $FC = \left(\frac{6000}{1+e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D*100))}}\right) * \left(\frac{1}{60}\right)$<br>$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$<br>$C_1' = -2 * C_2'$ | | |
| c1: 3.32 | c2: 1.25 | c3: 0 | c4: 1000 | c1: 0.5 | c2: 0.56 | c3: 6000 |
| **AC Cracking Top Standard Deviation** | | | | **AC Cracking Bottom Standard Deviation** | | |
| 150 + 2300/(1+exp(1.9-0.6*LOG10 (TOP+0.0001))) | | | | 0.7874+17.817/(1+exp(0.0699-0.4559*LOG10 (BOTTOM+0.0001))) | | |

| CSM Cracking | | | |
|---|---|---|---|
| $FC_{ctb} = C_1 + \frac{C_2}{1+e^{C_3 - C_4(Damage)}}$ | | | |
| C1: 1 | C2: 1 | C3: 0 | C4: 1000 |
| **CSM Standard Deviation** | | | |
| CTB*1 | | | |

| IRI Flexible Pavements | | | |
|---|---|---|---|
| C1 - Rutting<br>C2 - Fatigue Crack | | C3 - Transverse Crack<br>C4 - Site Factors | |
| C1: 50.372 | C2: 0.4102 | C3: 0.0066 | C4: 0.0068 |